

A review of the lanternfish genus *Bolinichthys* Paxton, 1972 (Myctophidae)

by

P. Alexander HULLEY (1) & Guy DUHAMEL (2)

ABSTRACT. - On the basis of data from 6,950 specimens, together with re-worked records from the collections of the world's major research institutions and museums, the lanternfish genus *Bolinichthys* (family Myctophidae) is reviewed. A key to, and descriptions of the seven species comprising the genus are given. The vertical and geographic distributions of the component species (*B. distofax*, *B. indicus*, *B. longipes*, *B. nikolayi*, *B. photothorax*, *B. pyrsobolus*, and *B. supralateralis*) are examined and discussed in relation to physical and biological oceanographic parameters. In most species there are correlations with water mass structure. However, the distribution of *B. supralateralis* demonstrates a more complex relationship to bottom topography and local current systems.

RÉSUMÉ. - Revue du genre *Bolinichthys* Paxton, 1972 (Myctophidae).

Sur la base de l'analyse de 6 950 spécimens, associée au ré-examen de données issues des collections d'instituts de recherche et de musées du monde entier, la taxinomie du genre *Bolinichthys* (Myctophidae) est révisée. Une clef et les descriptions des sept espèces qui forment le genre sont données. Les distributions verticales et géographiques des espèces (*B. distofax*, *B. indicus*, *B. longipes*, *B. nikolayi*, *B. photothorax*, *B. pyrsobolus*, et *B. supralateralis*) sont examinées et discutées par rapport aux paramètres d'océanographie physique et biologique. Pour la plupart des espèces, il y a des corrélations avec la structure de la masse d'eau. Cependant, la distribution de *B. supralateralis* démontre un rapport plus complexe avec la topographie du fond et la courantologie locale.

Key words. - Myctophidae - *Bolinichthys* - Lanternfishes - Taxonomy - Key to species - Distribution - Ecology.

During the course of investigations over the past 20-plus years into the systematics and distribution of lanternfishes (family Myctophidae), we have examined a large number of specimens of the genus *Bolinichthys* from the Atlantic, Indian and Pacific oceans (Tab. I). Data from these specimens and from the literature reveal that: (1) morphometric ranges for many of the published diagnostic characters overlap, thereby making species identifications using existing keys difficult; (2) numerous distributional records incorporated into systems like FishBase (Froese and Pauly, 2005) and the Global Biodiversity Information Facility (<http://www.gbif.org>) appear to be erroneous or questionable in terms of their taxonomic identity; such records unduly influence any ecological modelling of distribution, or of species-niche identification, as given on these websites; (3) adequate illustrations and descriptions for *B. nikolayi* and *B. pyrsobolus* are lacking in the literature; (4) knowledge of phenotypic plasticity within the genus is limited, since specimens of *Bolinichthys* with 4 VO photophores have recently been described as a new species, *Bolinichthys nanshanensis*, by Yang and Huang (1992); the genus is characterized by 5 VO photophores (Paxton, 1972). A systematic review of the

genus therefore appears to be overdue, and more particularly so because of the following observations.

Paxton (1972) distinguished the genus *Bolinichthys* (type-species *Myctophum (Lampanyctus) longipes* Brauer, 1906) from *Lepidophanes* Fraser-Brunner, 1949 (type species *Lampanyctus guentheri* Goode & Bean, 1896) on the basis of 3 (i.e., 2+1) Prc photophores; the presence of a crescent of white tissue in the posterior half of the iris; and numerous osteological characters (see generic diagnosis below). In addition, there are also marked differences in the shape of the posterodorsal margin the operculum in the two genera (Hulley and Paxton, in press). In *Bolinichthys*, the posterodorsal margin of the operculum is sharply pointed, while the rear margin is noticeably anteriorly concave and webbed with darkly pigmented skin, even in juvenile specimens. In *Lepidophanes*, both the posterodorsal and posterior margins of the operculum are broadly rounded and there is no web of pigmented skin.

In terms of phylogeny, the position of the genus *Bolinichthys* within the family Myctophidae is not well resolved, even to its inclusion within the tribe Lampanyctini. On the basis of the characters mentioned above (established by

(1) Department of Marine Biology, Iziko Museums of Cape Town, P.O. Box 61, Cape Town 8000, SOUTH AFRICA. [pahulley@iziko.org.za]

(2) Département des milieux et peuplements aquatiques, UMR 7208 BOREA, Muséum national d'Histoire naturelle, Case postale 26, 43 rue Cuvier, 75231 Paris CEDEX 05, FRANCE. [duhamel@mnhn.fr]

the examination of only six specimens of a single species, *B. longipes*), Paxton (1972: fig. 21) suggested that *Bolinichthys* is the sister-group to the *Lepidophanes-Ceratoscopelus* grouping, this cluster of three genera being itself a subgroup that includes *Taaningichthys* and *Lampadena* within the Lampanyctini. The inclusion of additional larval characters (Paxton *et al.*, 1984: fig. 125) in a subsequent phylogenetic analysis did not substantially alter this hierarchy. Previously, Moser and Ahlstrom (1972) and Ahlstrom *et al.* (1976) had included *Bolinichthys*, *Lampadena*, *Taaningichthys*, *Lepidophanes* and *Ceratoscopelus* in the tribe Gymnoscopelini. Here, these authors based their arguments primarily on photophore patterning during larval development. A later PAUP analysis of the Paxton *et al.* (1984) data by Stiassny (1996: fig. 21b) demonstrated considerable “phylogenetic space” between the *Lampadena-Taaningichthys* subgroup and *Bolinichthys*, although this latter genus was still “calculated” to be a sister-group to the *Ceratoscopelus-Lepidophanes* cluster. The incorporation of an additional six ctenosquamate characters into the PAUP analysis (Stiassny, 1996: fig. 21c) has only served to cloud the issue further, since the relationships of *Bolinichthys*, *Triphoturus*, *Stenobranchius*, *Parvilux*, *Lampanyctus*, *Lampadena*, *Taaningichthys*, *Ceratoscopelus*, *Lepidophanes* and the groupings incorporated into the tribes Diaphini and Gymnoscopelini now appear to be entirely unresolved. It should be noted however that no *Bolinichthys* material was examined for this ctenosquamate character analysis (Stiassny, 1996: Appendix 2).

Because the description of *Scopelus pyrsobolus* by Alcock (1890) was based on a single, damaged specimen (ca 78 mm TL), in which the positions of the photophores were not given, some eight species of *Bolinichthys* were subsequently described for similar or identical forms. This led Bolin (1959: 36) to opine (ambivalently) that only a single, widely distributed species was involved which “displays a much greater range of variation than is normally found in other members of the family, or with a constellation of very closely related species with overlapping geographic ranges”. He therefore synonymised all the known species into a single species, *Lepidophanes pyrsobolus*. Successive research, including a re-description of Alcock’s type specimen by Misra (1949; 1952) and the determination of *Lepidophanes blacki* as a junior synonym of *L. pyrsobolus* by Paxton (1979), has seen the resurrection of several species.

In terms of species richness, Paxton (1979) listed seven valid species in the genus, namely: *Bolinichthys pyrsobolus* Alcock, 1890 – with *Serpa blacki* Fowler, 1934 a junior synonym; *Bolinichthys longipes* Brauer, 1906 – with the junior synonyms *Lampanyctus joubini* Angel & Verrier, 1931, *Macrostoma grayi* Fowler, 1938 and *Lampanyctus fraserbrunneri* Bolin, 1946; *Bolinichthys supralateralis* Parr, 1928; *Bolinichthys photothorax* Parr, 1928 – with the junior synonym *Lampanyctus stilbius* Gilbert, 1908; *Bolinichthys*

indicus Nafpaktitis & Nafpaktitis, 1969; *Bolinichthys distofax* Johnson, 1975; and *Bolinichthys nikolayi* Becker, 1978. Arguments were presented to substantiate these synonymies (Paxton, 1979: 6). More recently, Yang and Huang (1992) have described *Bolinichthys nanshanensis* from the South China Sea.

The phylogenetic relationships between the species are unknown, although Johnson (1975) did attempt to structure the genus on an anatomical basis. He recognized two groups of species: Group 1 – species with VLO at or less than one photophore diameter below the lateral line (*B. indicus*, *B. longipes* and *B. photothorax*); and Group 2 – species with the VLO 3.0-3.5 times its own diameter below the lateral line (*B. blacki* (= *B. pyrsobolus*), *B. distofax* and *B. supralateralis*). Within the second group, Johnson (1975) pointed to the similarity between *B. distofax* and *B. supralateralis*, namely in the elevation of VO₂ in relation to line through VO₃-VO₅ when compared to *B. blacki*, and he quantified that expression (Johnson, 1975: fig. 3).

Further analysis and discussion of the phylogeny of the genus is beyond the scope of the present paper.

Finally, the distributions of *Bolinichthys* species have only been described in broad-brushed statements, or on the basis of point data (Nafpaktitis and Nafpaktitis, 1969; Backus *et al.*, 1970; Kotthaus, 1972a, 1972b; Krefft and Becker, 1973; Johnson, 1975; Wisner, 1976; Nafpaktitis *et al.*, 1977; Krefft, 1978; Gorelova, 1978; Hulley, 1981, 1984a, 1986a, 1990; McGinnis, 1982; Becker, 1983; Kinzer *et al.*, 1994; Paxton and Hulley, 1999, 2000; Craddock and Hartel, 2002; Hulley and Paxton, in press). Little attempt has been made to identify distributional limits and associated hydrographic parameters, or to draw inferences on the degree of niche separation / overlap for species within *Bolinichthys*. Some depth distribution and reproductive details for one of the species (*B. indicus*) from the Bermuda Ocean-Acre region have been presented by Karnella (1987).

MATERIAL AND METHODS

The material examined during the course of this investigation is given in table I.

Details of nets, sampling methodology and geographic location for the various cruises have already been presented in the literature, namely: RS *Africana*, RS *Africana II*, Cruises deep-sea, 60, 80 (Hulley, 1972a; 1972b; 1992; Augustyn and Hulley, 1988); FFS *Anton Dohrn*, Cruise 1979 (Hulley and Krefft, 1985; Post, 1987); NO *Coriolis*, Bora Cruises 1-3 (Rotschi *et al.*, 1967; Magnier *et al.*, 1967; Lemasson *et al.*, 1967a; 1967b); NO *Coriolis*, Caride Cruises 1-6 (Repelelin *et al.*, 1969; Voituriez *et al.*, 1969; Donguy *et al.*, 1970; Legand *et al.*, 1972); NO *Coriolis*, Pelagia Cruises 1-3 (Hulley and Duhamel, 1997); NO *Marion Dufresne*, Cruise 50

Table I. - List of material.

Ship name or data source	Cruise or compiler	Year	Total no [Σ N]	<i>B. distofax</i> No spec. N	<i>B. indicus</i> No spec. N	<i>B. longipes</i> No spec. N	<i>B. pyrsobolus</i> No spec. N	<i>B. nikolayi</i> No spec. N	<i>B. photothorax</i> No spec. N	<i>B. supralateralis</i> No spec. N
FFS Anton Dohrn	176 (58)	1974	60	1	2	0	0	0	37	20
FFS Anton Dohrn	210 (92) (Part 2)	1979	879	0	830	0	0	0	24	25
RS Africana	60	1988	167	0	1	0	0	0	0	166
RS Africana II	80	1990	6	0	6	0	0	0	0	0
NO Coriolus	Bora-1	1965	2	1	0	1	0	0	0	0
NO Coriolus	Bora-2	1966	42	5	0	30	0	0	7	0
NO Coriolus	Bora-3	1966	37	5	0	27	1	0	4	0
NO Coriolus	Caride-1	1968	1034	1	0	997	2	0	34	0
NO Coriolus	Caride-2	1968	1201	2	0	1140	3	4	52	0
NO Coriolus	Caride-3	1969	1314	3	0	1265	4	4	38	0
NO Coriolus	Caride-4	1969	343	0	0	321	2	0	20	0
NO Coriolus	Caride-5	1969	496	1	0	464	0	13	18	0
NO Coriolus	Caride-6	1969	76	0	0	48	6	0	22	0
NO Coriolus	Pelagia-1	1971	16	0	0	12	0	1	3	0
NO Coriolus	Pelagia-2	1971	7	0	0	7	0	0	0	0
NO Coriolus	Pelagia-3	1971	24	0	0	15	0	9	0	0
Miscellaneous	n/a	n/a	66	3	6	34	15	7	1	0
NO Marion Dufresne	50/IASUS	1986	2	0	2	0	0	0	0	0
RS Meiring Naude	SAM-2	1975	21	0	10	0	0	0	0	11
FFS Walther Herwig (I)	15, 23, 36 (Part 2)	1966-1971	862	141	208	0	0	0	459	54
FFS Walther Herwig (II)	Vorbereitungs Reise	1975	5	0	5	0	0	0	0	0
FFS Walther Herwig (II)	20	1975-1976	18	0	17	0	0	0	0	1
FFS Walther Herwig (III)	52 (Part 2)	1982	35	0	6	0	0	0	0	29
FFS Walther Herwig (III)	58 (TIFI-8)	1983	2	0	0	0	0	0	0	2
JRP	J.R. Paxton	n/a	235	12	62	16	6	71	22	46
TOTAL			6950	175	1155	4377	39	109	741	354

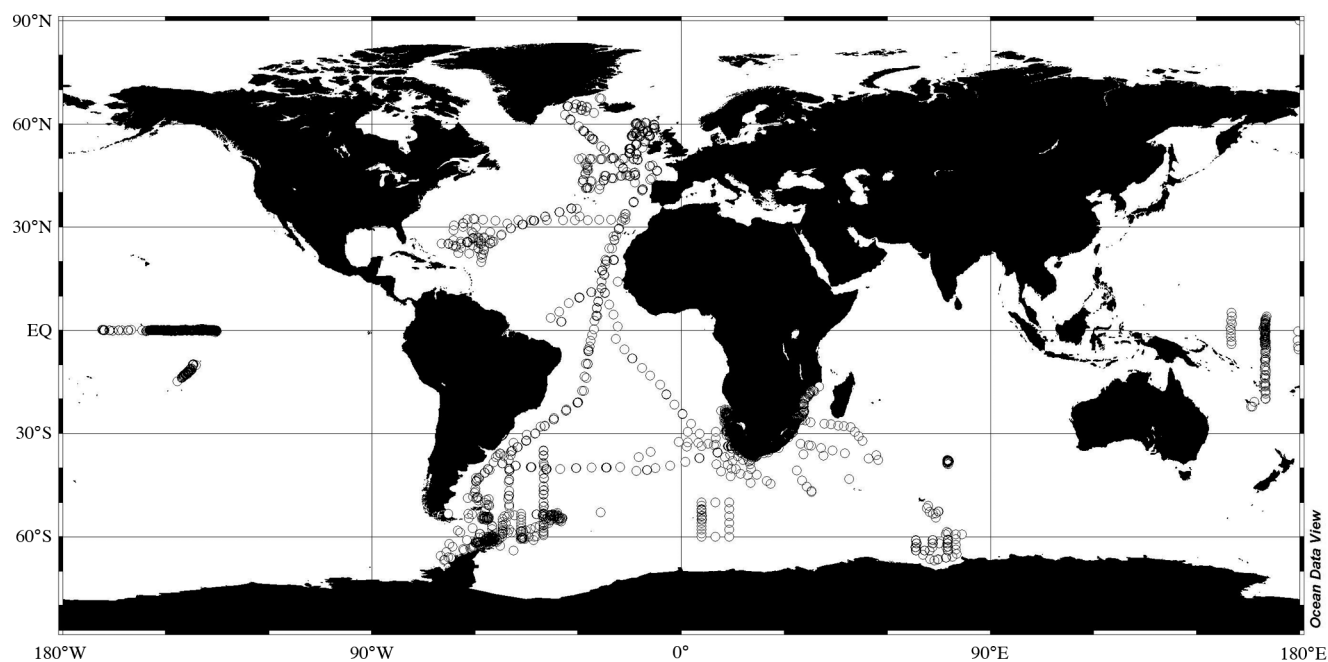


Figure 1. – Sampling stations occupied during *Africana*, *Africana II*, *Anton Dohrn*, *Coriolis*, *Marion Dufresne*, *Meiring Naude* and *Walther Herwig* cruises.

Bora + Caride Stations: IKMT-10
n = 1069

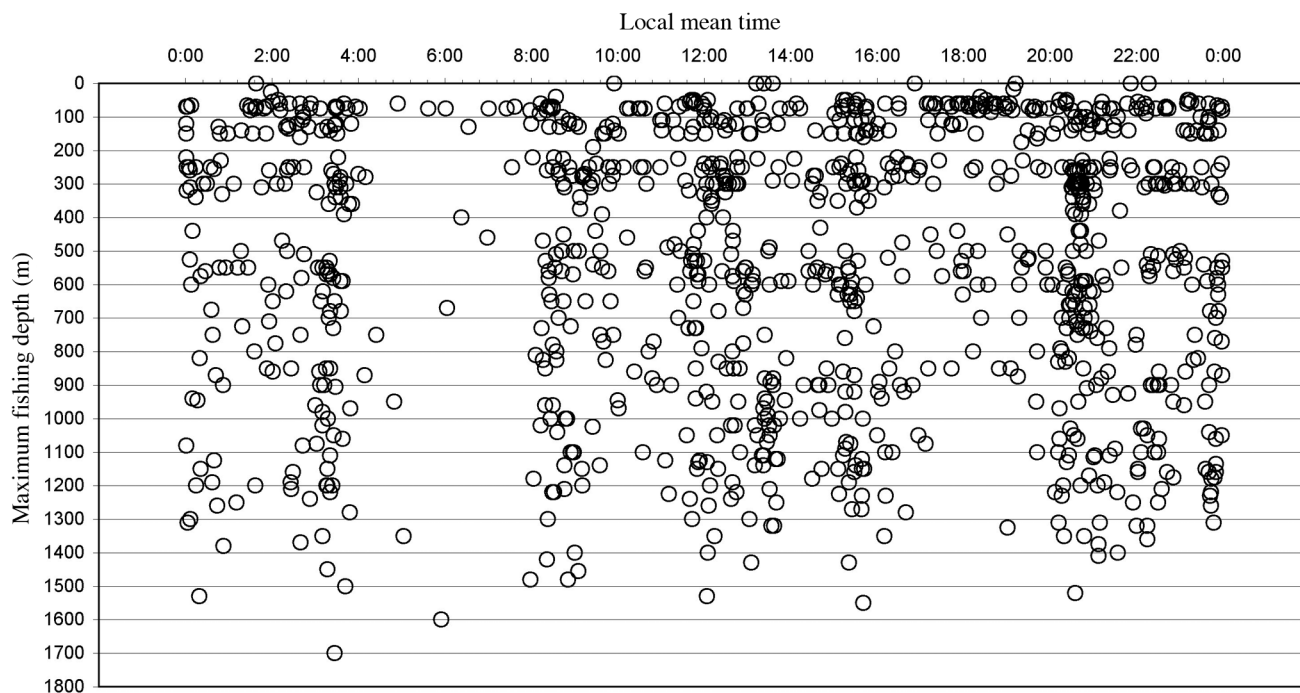


Figure 2. - Diel distribution of 1069 stations occupied with non-closing IKMT-10 during *Bora* and *Caride* cruises of NO *Coriolis* in the equatorial and tropical Pacific Ocean.

Table II. - *Bolinichthys*. Meristics (modal values highlighted).

Dorsal rays	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
<i>B. distofax</i>											6	55	3									
<i>B. indicus</i>											28	60	2									
<i>B. longipes</i>											2	10	1									
<i>B. nikolayi</i>									1	4	21	46										
<i>B. photothorax</i>											10	93	1									
<i>B. pyrsobolus</i>										1	6	11										
<i>B. supralateralis</i>											6	104	5									
Anal rays	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
<i>B. distofax</i>												16	46	2								
<i>B. indicus</i>											14	55	19	1								
<i>B. longipes</i>												1	10	4								
<i>B. nikolayi</i>									1	2	9	15	34									
<i>B. photothorax</i>												7	81	15								
<i>B. pyrsobolus</i>											2	13	2	1								
<i>B. supralateralis</i>											1	6	96	11								
Pectoral rays	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
<i>B. distofax</i>											2	35	13									
<i>B. indicus</i>												8	62	2								
<i>B. longipes</i>												9	3									
<i>B. nikolayi</i>									2	30	35											
<i>B. photothorax</i>												2	38	59								
<i>B. pyrsobolus</i>											8	8	5	3	1							
<i>B. supralateralis</i>												1	14	7								
AOa photophores	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
<i>B. distofax</i>			2	51	99	6																
<i>B. indicus</i>			2	41	126	9																
<i>B. longipes</i>			54	537	58																	
<i>B. nikolayi</i>			11	30	60	2																
<i>B. photothorax</i>				27	92	160	1															
<i>B. pyrsobolus</i>			4	30	5																	
<i>B. supralateralis</i>			1	31	163	16																
AOp photophores	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
<i>B. distofax</i>			13	125	19																	
<i>B. indicus</i>	1	7	122	40																		
<i>B. longipes</i>			174	433	42																	
<i>B. nikolayi</i>	12	60	5																			
<i>B. photothorax</i>			7	162	132	1																
<i>B. pyrsobolus</i>			29	9																		
<i>B. supralateralis</i>			14	189	7																	
AO photophores (total)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
<i>B. distofax</i>							5	39	106	7												
<i>B. indicus</i>							5	24	112	27	2											
<i>B. longipes</i>						1	154	459	35													
<i>B. nikolayi</i>					6	6	19	39	4													
<i>B. photothorax</i>								7	66	171	48											
<i>B. pyrsobolus</i>						2	26	9	1													
<i>B. supralateralis</i>							2	30	168	10												

Table II. - *Continued.*

Gill rakers (upper)		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
<i>B. distofax</i>				2	102	3																	
<i>B. indicus</i>			5	111	5																		
<i>B. longipes</i>			4	551	129																		
<i>B. nikolayi</i>			8	87																			
<i>B. photothorax</i>					29	134	10																
<i>B. pyrsobolus</i>					15	15																	
<i>B. supralateralis</i>					10	117	8																
Gill rakers (lower)		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
<i>B. distofax</i>										10	88	9											
<i>B. indicus</i>									6	22	61	22											
<i>B. longipes</i>									26	353	265	40											
<i>B. nikolayi</i>							1	4	59	28	3												
<i>B. photothorax</i>											1	4	56	84	29	2							
<i>B. pyrsobolus</i>										1	8	13	5										
<i>B. supralateralis</i>											4	82	85	23	1								
Gill rakers (total)		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
<i>B. distofax</i>															1	10	84	12					
<i>B. indicus</i>														2	24	54	20	3					
<i>B. longipes</i>													2	26	337	210	93	28					
<i>B. nikolayi</i>											1	4	61	28									
<i>B. photothorax</i>																		1	17	50	72	26	7
<i>B. pyrsobolus</i>																		7	8	10	5		
<i>B. supralateralis</i>																		11	77	78	24	3	

(Hulley and Duhamel, 1990); RS *Meiring Naude*, Cruises SAM (Louw, 1977; 1980; Hulley, 1984b); and FFS *Walther Herwig*, Cruises 1966, 1968, 1972, 1974, 1975, 1976, 1982, 1983 (Hulley, 1981; Merrett *et al.*, 1986; Post, 1987; Fock *et al.*, 2004). The geographic positions of the 2,512 stations occupied during these cruises is given in figure 1.

For the *Bora* and *Caride* cruises and in order to examine diel vertical migration behaviour in certain species, the maximum sampling depth for each station with respect to Local Mean Time at the commencement of trawling is given in figure 2. The 10' IKMT deployed during these cruises was a non-closing net, so that fishing is theoretically possible during the entire trajectory of the oblique haul. Variability in these samples has been discussed by Legand *et al.* (1972).

Material from all of the above-named cruises (or subsamples of specimens from particular stations) is preserved in the collections of the Australian Museum, Sydney (AMS); Iziko Museums of Cape Town-South African Museum (SAM); Museum national d'Histoire naturelle, Paris (MNHN); Zoologisches Museum, Hamburg (ISH); Zoologisk Museum, Copenhagen (ZMUC); and the United States National Museum of Natural History, Washington (USNM).

Meristic, morphometric, locality and photographic data on additional specimens were supplied by the Collection Managers and Curators at the following institutions: British

Museum of Natural History (BMHN); California Academy of Sciences, San Francisco (CAS); Humboldt University Museum, Berlin (ZMB); Institute of Oceanology, Moscow (IOM); Los Angeles County Museum of Natural History (LACM); Museum of Comparative Zoology, Harvard (MCZ); and Scripps Institution of Oceanography, San Diego (SIO).

Distributional point-data records were also obtained from FishBase (Froese and Pauly, 2005) and the GBIF portal (<http://www.gbif.org/>), and with search engines at the Internet sites of the following institutions: American Museum of Natural History (New York); Bernice P. Bishop Museum (Hawaii); California Academy of Sciences (San Francisco); CSIRO (Hobart), through Australia's Faunal portal; Field Museum of Natural History (Chicago); Fishbases of Japan, through Ocean Research Institute (Tokyo) portal; Yale Peabody Museum (New Haven); and the University of Washington (Seattle). Where some of these records appeared to be anomalous, the curators very kindly provided supplementary data on the specimens concerned.

All measurements were taken to the nearest 1 mm with digital sliding callipers, in accordance with Hubbs and Lagler (1947) and Nafpaktitis and Nafpaktitis (1969). The data have either been digitally transferred directly to a database developed for the purpose, using an R232 interface; or

Table III. - *Bolinichthys*. AO counts and distributions (modal values high-lighted).

<i>B. distofax</i>	AOa / AOp	2	3	4	5	6
	4				2	
	5		5	33	12	
	6		4	90	5	
	7		4	2		
	8					
<i>B. indicus</i>	AOa / AOp	2	3	4	5	6
	4				2	
	5		4	26	18	
	6	1	3	86	18	
	7			7	1	
	8					
<i>B. longipes</i>	AOa / AOp	2	3	4	5	6
	4		1	31	22	
	5		123	394	20	
	6		50	8		
	7					
	8					
<i>B. nikolayi</i>	AOa / AOp	2	3	4	5	6
	4	6	4			
	5	2	16	2		
	6	3	36	3		
	7	1	1			
	8					
<i>B. photothorax</i>	AOa / AOp	2	3	4	5	6
	4					
	5			7	20	
	6			48	54	1
	7		7	104	48	
	8			1		
<i>B. pyrsobolus</i>	AOa / AOp	2	3	4	5	6
	4		2	2		
	5		24	4		
	6		3	1		
	7					
	8					
<i>B. supralateralis</i>	AOa / AOp	2	3	4	5	6
	4				1	
	5		2	26	3	
	6		3	155	3	
	7		9	7		
	8					

were manually transferred to data capture sheets for later incorporation into the database. Morphometric abbreviations follow Nafpaktitis (1978b). Photophore nomenclature

is in accordance with Nafpaktitis and Nafpaktitis (1969) and Paxton (1972). Meristic counts for each species are given in tables II-IV. Gill-raker counts for the lower limb of the first gill arch (GR_l) do not include the single raker at the angle of the gill arch, as this is a feature common to all myctophids; the total gill-raker count must therefore be calculated as GR_u + 1 + GR_l. In certain cases, specimens were sexed, and where possible, females were staged according to Hulley (1984b). Characters common to all species are in the genus definition and not repeated in the species descriptions.

The distribution map for *B. distofax* was created with Versamap Version 3.01, in combination with physical data sets derived from the literature and/or digitized from Internet data sources using WinDIG Version 2.5. Ocean Data-View (Schlitzer, 2005) was used to construct visual correlations of distributional data with oceanographic data sets in ODV format. These latter data included: monthly, seasonal and annual hydrographic data from U.S. NODC World Ocean Atlas 2005 (<http://odv.awi.de/data/ocean/world-ocean-atlas-2005.html>); and the global collection of historical hydrographic and nutrient data compiled by Reid and Mantyla (<http://odv.awi.de/data/ocean/reid-mantyla.html>). The ODV-programme and oceanographic data sets were downloaded from the Alfred-Wegener Institute website (<http://odv.awi.de>).

TAXONOMY

GENUS *BOLINICHTHYS* PAXTON, 1972

Bolinichthys Paxton, 1972: 46 (type-species: *Myctophum (Lampanyctus) longipes* Brauer, 1906 - by original designation).

Synonyms

None

Diagnostic features

Posterodorsal margin of operculum angulate, with marked anteriorly-directed concavity, webbed with darkly pigmented skin; crescent of whitish tissue on posterior iris; Dn absent; Vn small; 5 PO with PO₄ markedly elevated; 5 VO (usually 4 VO in *B. pyrsobolus*), with VO₂ elevated; 3 SAO, broadly to very broadly angulate; AO series divided into AOa and AOp; 2 Pol (counted in all cases: see discussion below); 2 + 1 Prc; luminous tissue at base of dorsal, anal, and in some species pelvic fins, and on head and trunk; absence of a keel on CO₃; extensive shelf on the CO₄; jaws extending one-half eye diameter or less behind posterior margin of orbit; enlarged dentigerous area on the anterior portion of the premaxilla; opercular head of hyomandibula without dorsal process; anterior tip of urohyal with one head; first pharyngobranchial with 1-2 tooth plates; moder-

Table IV. - *Bolinichthys*. GR counts and distributions (modal values highlighted).

	GRu / GRI	6	7	8	9	10	11	12	13	14	15	16
<i>B. distofax</i>	3											
	4					1	1					
	5					9	84	9				
	6						3					
	7											
<i>B. indicus</i>	GRu / GRI	6	7	8	9	10	11	12	13	14	15	16
	3					1	4					
	4				6	21	54	20				
	5						3	2				
	6											
<i>B. longipes</i>	GRu / GRI	6	7	8	9	10	11	12	13	14	15	16
	3				2	2						
	4				24	329	186	12				
	5					22	79	28				
	6											
<i>B. nikolayi</i>	GRu / GRI	6	7	8	9	10	11	12	13	14	15	16
	3		1	1	3	3						
	4	1	3	58	25							
	5											
	6											
<i>B. photothorax</i>	GRu / GRI	6	7	8	9	10	11	12	13	14	15	16
	3											
	4											
	5							1	15	11	2	
	6							2	39	69	22	2
<i>B. pyrsobolus</i>	GRu / GRI	6	7	8	9	10	11	12	13	14	15	16
	3											
	4											
	5					1	6	6	2			
	6						2	8	5			
<i>B. supralateralis</i>	GRu / GRI	6	7	8	9	10	11	12	13	14	15	16
	3											
	4											
	5							7	3			
	6					4	77	78	21	1		
<i>B. distofax</i>	7						1	5	2			

ate ischial ligament; first epural over anterior part of terminal vertebra; and procurent caudal rays with strongly fused tips and without spines.

L. gaussi, there are no post-ocular photophores, and there are always 2-4 (usually 3) scale-like patches of luminous tissue along the bases of the dorsal and anal fins.

Habitat and distribution

Generally oceanic, mesopelagic distribution dependant on dynamic structure of water masses; one species associated with continental and insular slope regions and local current systems; worldwide between 40°N and 40°S, but to 45°S in central Indian Ocean, to 50°S off Tasmania, and to 58°N in eastern North Atlantic.

Discussion

The selection of *Bolinichthys longipes* as the type-species for the genus (Paxton, 1972) was perhaps not judicious. Problems exist with regard to the identity of the 14 syntypes (from 10 localities) employed in Brauer's (1906) original description of *Myctophum (Lampanyctus) longipes*. According to Krefft and Becker (1973) and Paxton (1979) four syntypes (from two localities: ZMB 17612 ('Valdivia' Stn. 215: 07°1'2" N, 085°56'5" E: 2 specimens); 17613 ('Valdivia' Stn. 217: 04°56' N, 078°15'3" E: 2 specimens) are referable to *Bolinichthys longipes*, since type specimens from near Madeira ('Valdivia' Stn. 26: 31°59'03"N, 015°5'00"W) and the Gulf of Guinea ('Valdivia' Stn. 64: 00°25'08"N, 007°00'03"E) should be referred to *B. indicus*. In addition, of the eight Indian Ocean type-locality records for *B. longipes* originally listed by Brauer (1906), one record is from further south than 20°S ('Valdivia' Stn. 175: 26°03'06"S, 93°14'09"E), and so might also be referable to *B. indicus* by virtue of its distribution (see below; and compare with Nafpaktitis and Nafpaktitis, 1969: fig. 72). None of this latter type material can be found at ZMB (Dr. Peter Bartsch, pers. comm.). To complicate matters further, Brauer (1904: 395) used the key characters of an elevated PO₅ and VO₂ in combination with "... je eine Leuchtschuppen an der Basis der A, V und D, 3 post-ocular Leuchtorgane ..." to identify *Myctophum (Lampanyctus) guntheri* (= *Lepidophanes guntheri*). These characters are indicative of those species now referable to the genus *Bolinichthys*, rather than to those referable to *Lepidophanes*. In both *L. guntheri* and

The separation of the genus into two species groups by Johnson (1975), on the basis of the position of the VLO in the then-known species, suggests cut-off values of < 1 diameter (Group 1) or > 3.0 diameters (Group 2) for the position of VLO below lateral line. However, examination of additional material in all these species, and of specimens of *Bolinichthys nikolayi*, indicates a more continuous gradation, rather than a truly dichotomous condition for the character. A critical value of VLO about 2 photophore diameters below the lateral line would apply as a diagnostic in the majority of cases, provided that additional characters such as the presence/absence of a luminous scale at the pelvic base; presence/absence of post-ocular photophores; and the relationships of the Op₁-Op₂ interspace to the distance PVO₁-PVO₂ are also used (*vide* Key to Species). Small specimens of *B. nikolayi* can be especially problematic, with some clearly having the VLO < 2 diameters below the lateral line. Johnson's (1975) investigations into the orientation of the VO series certainly delimit two additional subgroupings within his Group 2 species: (1) VO₂-VO₅ in a straight, oblique line (*B. distofax* and *B. supralateralis*); and (2) VO₂-VO₅ distinctly angulate (*B. nikolayi* and *B. pyrsobolus*). His Group 1 species may also be separated into two subgroups by the presence/absence of an anteriorly, recurved spine at the posteroventral margin of the preopercle (*B. photothorax* vs. *B. longipes-indicus* complex respectively) (Hulley, 1981).

Yamaguchi *et al.* (2000) have pointed out that clade recognition (Clade C), determined by nucleotide sequencing of the 16S ribosomal RNA gene in seven species of *Hygophum* (all of which are characterized by 2 Pol), is supported by the orientation of the Pol with respect to the last AOa photophore. A count of 1 Pol or 2 Pol in the various species descriptions of *Bolinichthys* therefore calls for comment, because this distinction not only affects the values of the AOa counts directly, but may also have phylogenetic implications. Paxton *et al.* (1984: 242) consider "the primitive myctophid state to be one with low photophores, with none or one Pol (character 34)". They assign a value of 2 Pol for *Bolinichthys* (1984: tables 63, 64: character 34, character state (2) – i.e., an advanced apomorphic state), rather than 1-2 Pol (character 34, character state (1) – i.e., an apomorphic state), in line with Paxton's (1972) original generic description. However, published species descriptions have variously recognized 1 Pol: Angel and Verrier (1931), Fraser-Brunner (1949), Nafpaktitis and Nafpaktitis (1969), Kotthaus (1972b), Johnson (1975), Becker (1978); 1-2 Pol: Nafpaktitis *et al.* (1977); and 2 Pol: Brauer (1906), Fowler (1934), Bolin (1946), Paxton (1972), Hulley (1972a; 1981; 1984a; 1986a; 1986b), Wisner (1976), Paxton *et al.* (1984; 1995), Yang and Huang (1992), (Hulley and Paxton, in Press). In this paper, 2 Pol have been recognized and counted in all cases.

KEY TO SPECIES OF *BOLINICHTHYS*

- 1a. VLO 2-5 photophore diameters below lateral line (except some small *B. nikolayi*); distance PVO₁-PVO₂ less than or subequal to distance Op₁-Op₂; luminous scale at pelvic fin base absent; small post-ocular photophores absent **2**
- 1b. VLO about one photophore diameter (or slightly less or slightly more) below lateral line; distance PVO₁-PVO₂ greater than distance Op₁-Op₂; luminous scale at pelvic fin base present; 3 small post-ocular photophores present **5**
- 2a. VO₂ elevated, but distinctly below line through PO₄-SAO₁; VO₂-VO₅ in a straight, oblique line; ventral edge of interopercle serrate (specimens longer than 30 mm SL) . . . **3**
- 2b. VO₂ highly elevated, touching line through PO₄-SAO₁; VO₂-VO₅ distinctly angulate; ventral edge of interopercle smooth (specimens longer than 30 mm SL) **4**
- 3a. GR 6 (5-7) + 1 + 12-13 (11-15), total 19-20 (18-22) (Tabs. II, IV for distribution of values); 2 Pol, with Pol₁ elevated above AOa series, and on vertical through middle of base of adipose fin; Vn below anterior margin of orbit *B. supralateralis*
- 3b. GR 5 (4-6) + 1 + 11 (10-12), total 17 (15-18) (Tabs. II, IV for distribution of values); 2 Pol, with Pol₁ level with or slightly raised above AOa series to appear as part of AOa series, on vertical through origin of adipose fin; Vn below anterior margin of pupil *B. distofax*
- 4a. GR 4 (3) + 1 + 8-9 (6-10), total 13 (11-14) (Tabs. II, IV for distribution of values); 5 (rarely 4) VO; VLO closer to lateral line than to outer pelvic base; 5-7 luminous 'scales' above anal base; infracaudal luminous tissue reaching to AOp₁; P 10 *B. nikolayi*
- 4b. GR 5-6 + 1 + 12 (10-13), total 19 (17-20) (Tabs. II, IV for distribution of values); 4 (rarely 5) VO; VLO about midway between lateral line and outer pelvic base, or only slightly closer to lateral line; 3-5 luminous 'scales' above anal base ('scales' absent in specimens less than 12 mm SL); infracaudal luminous tissue reaching to AOp₂-AOp₃; P 12-13 *B. pyrsobolus*
- 5a. Preopercle with strongly developed, anteriorly-recurved spine at posteroventral margin (Fig. 40); luminous patch at PVO₁ present *B. photothorax*
- 5b. Preopercle with only small protuberance at posteroventral margin; luminous patch at PVO₁ absent **6**
- 6a. Distance between posterior cusps of posterodorsal concavity in operculum subequal or only slightly larger than base of pectoral fin (Fig. 10); luminous patch above pectoral base present; typically (but not always) with infracaudal luminous tissue extending anteriorly at least to last AOp, or even more anteriorly (Fig. 11) *B. indicus*
- 6b. Distance between posterior cusps of posterodorsal concavity in operculum about twice as long as base of pecto-

ral fin (Fig. 19); luminous patch above pectoral base absent; typically (but not always) with infracaudal luminous tissue not reaching to last AOp (Fig. 20) *B. longipes*

TAXONOMY

BOLINICHTHYS DISTOFAX JOHNSON, 1975

(Figs 3-8; Tabs I-IV)

Synonymy

Bolinichthys distofax Johnson, 1975: 53, figs. 1-4 (Mauna Loa lava flow, Hawaii). Holotype: CAS 15998; 89 paratypes; CAS 15995 (5 spec.), 15996 (9 spec.); 15997 (12 spec.), 15998 (43 spec.), 29194 (5 spec.), SIO 60-249 (2 spec.), 60-251 (10 spec.), 70-334 (1 spec.), 71-307 (1 spec.), 70-373 (1 spec.).

Lepidophanes pyrsobolus (non Alcock, 1890): Becker, 1967a: 116 (*partim*) Becker, 1967b: tab. 3.

Bolinichthys supralateralis (non Parr, 1928): Clarke, 1973: 422; Moser and Ahlstrom, 1974: fig. 11D; Wisner, 1976: 200-202, fig. 188 (*partim*)

Bolinichthys sp.: Hartmann and Clarke, 1975: 637; Boehlert and Mundy, 1993: tab. 3.

Bolinichthys distofax: Nafpaktitis *et al.*, 1977: 234-236, fig. 164; Backus *et al.*, 1977: 267; Parin *et al.*, 1977: 127, fig. 21; Becker, 1978: fig. 2 (3); 1983: 213, figs. 49 (v), 99 (7); Tinker, 1978: 95; Paxton, 1979: 7; Loeb, 1979a: tab. 2; 1979b: 787, tabs. 2-3; 1986: fig. 4; Hulley, 1981: 225-227, fig. 104; 1990: 400; Johnson, 1982: 183; Barnett, 1984: 204; Moser *et al.*, 1984: 236, tab. 61, fig. 122; Kailola, 1987: 99; Fujii, 1984: 69, pl. 66-G; Childress *et al.*, 1990: tab. 1; Butler *et al.*, 1997: 18, tab. 3, fig. 22; Paxton and Hulley, 1999: 1962; Moser and Watson, 2001: 60, tabs. 1-3, fig.; 2006: 522, fig; Craddock and Hartel, 2002: 950; Mundy, 2005: 211; dos Santos, 2003: 14-16, 2 tables, fig.; Froese and Pauly, 2005; Eschmeyer, 2008; Hulley and Paxton, in press.

Bolinichthys sp. II: Ozawa, 1986: 154-155.

Bolinichthys distophax: Nakabo, 2000: 378; 2002, 378, fig.; Shinohara *et al.*, 2001: 301; 2005: 411.

Meristics

D 13 (12-14); A 14 (13-15); P 12 (11-13); AO 6 (3-5) + 4 (3-5), total 10 (8-11); GR 5 (4-6) + 1 + 11 (10-12), total 17 (15-18).

GR counts from Pacific and Atlantic populations are not statistically significantly different (GR_u: $t = -2.6073$, $df = 105$; GR_l: $t = 0.0000$, $df = 105$; GT_T: $t = -1.0539$, $df = 105$).

Description

Eye large, aphakic space present; crescent of white tissue on posterior half of iris. Large re-curved preopercular spine absent. Posterodorsal margin of operculum anteriorly concave, distance between cusps about one-and-a-half times pectoral base; subopercle and interopercle serrate (speci-

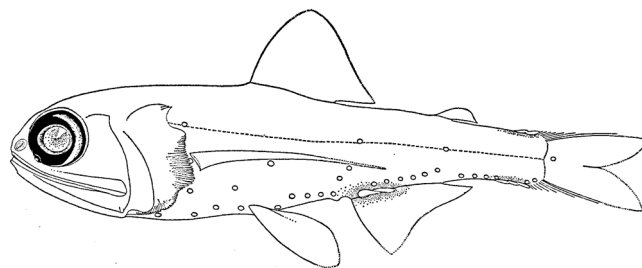


Figure 3. - *Bolinichthys distofax*. Paratype (SIO 73-327), SL 77.3 mm (from Nafpaktitis *et al.*, 1977).

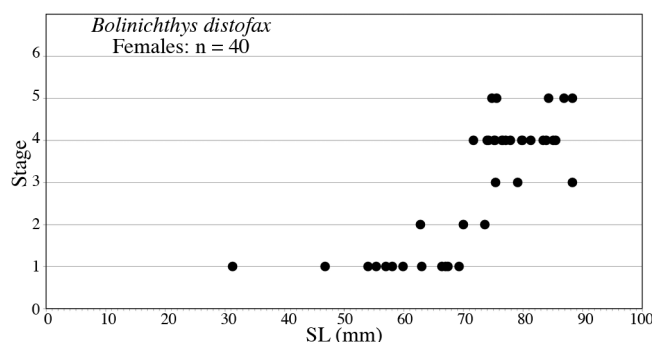


Figure 4. - *Bolinichthys distofax*. Relationship of sexual maturity to standard length (SL).

mens longer than 30 mm SL). Origin of dorsal fin about on vertical through outer base of pelvic fin; origin of anal fin behind vertical through posterior end of base of dorsal fin; pectoral fins long, reaching to AOa₂; pelvic fins reaching to beyond origin of anal fin; adipose origin in advance of end of base of anal fin.

Vn at anteroventral border of eye, on or posterior to a vertical through anterior margin of pupil; in some small post-larval specimens (ca. 15 mm SL) Vn may be situated in front of vertical through anterior margin of pupil (MNHN 1997-0866; MCZ 91051). Small post-ocular photophores absent. Op₁ below level of posterior angle of mouth, just above ventral margin of posterior flange of preopercle; Op₂ larger, at about level of ventral margin of orbit. PLO at or just above lateral line. 5 PO; with PO₃ raised above line through centres of PO₁-PO₂; with PO₄ at about level of PVO₁, and nearer to PO₅ than PO₃; and with PO₅ in front of outer pelvic base. VLO 2-5 photophore diameters below lateral line, posterior to vertical through outer pelvic base. 5 VO; with VO₂ elevated, but distinctly below line connecting PO₄-SAO₁; and with VO₂-VO₅ in a straight, oblique, descending line. SAO₁ posterior to vertical through VO₅, slightly above level of PO₄; SAO₂ about over origin of anal fin, and nearer to SAO₁ than SAO₃; and with SAO₃ at or just above lateral line, posterior to vertical through origin of anal fin. AO series divided into AOa and AOp with AOa₁ and last AOa level; AOp evenly spaced and all posterior to end of anal fin. 2 Pol (by definition), with Pol₁ only slightly raised above AOa series, about

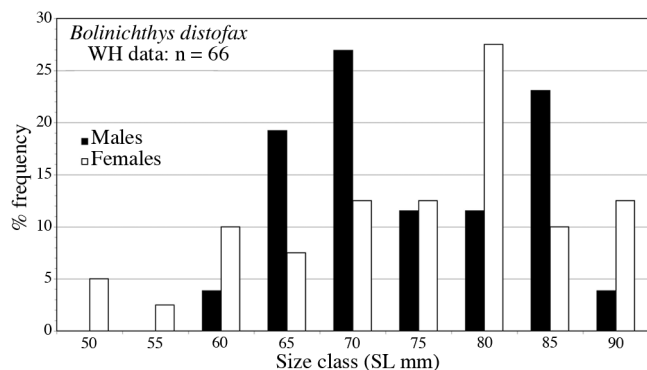


Figure 5. - *Bolinichthys distofax*. Length-frequency histograms for males and females.

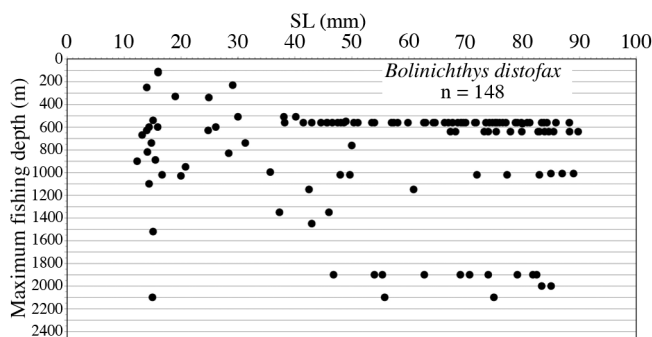


Figure 6. - *Bolinichthys distofax*. Variation of standard length (SL) with maximum fishing depth of haul.

on vertical through origin of adipose fin; and Pol_2 at lateral line, on vertical through last ray of anal fin. $2+1$ Prc; with Prc₂ 1 photophore diameter posterodorsad to Prc₁; and with Prc₃ well behind Prc₂ and above level of lateral line. Supracaudal luminous organ consisting of 2 (1-2) luminous scale-like structures; infracaudal luminous organ with 3 (2-4) similar structures, extending in both sexes from under Prc₁ to last AOp. Two (rarely 1 or 3) elongate, luminous patches along base of anal fin. No patches of luminous tissue elsewhere on head or body.

Size and maturation

Maximum size to 90 mm SL; females sexually mature from about 72 mm SL (Fig. 4), and taken only below 500 m. No apparent sexual dimorphism in size (Fig. 5). In the Atlantic Ocean, gravid females have been taken in February and April, suggesting a late summer spawning period at depth. Developmental stages have been given by Moser *et al.* (1984).

Depth distribution

Oceanic, mesopelagic species, apparently deep-living, with non-migrating adults. Generally, adults (> 40-50 mm SL) most commonly taken below about 510-550 m; very small juveniles (AM I 19740009: 16 mm SL; MCZ 123736:

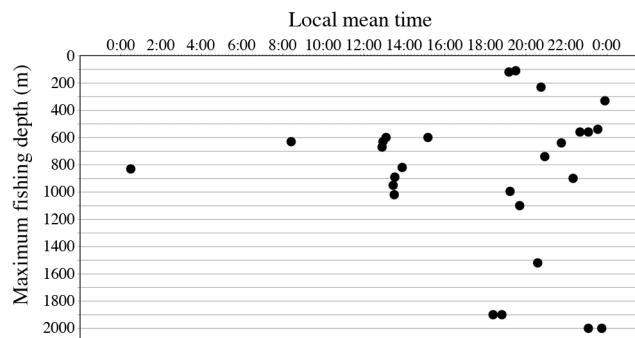


Figure 7. - *Bolinichthys distofax*. Diel vertical migration pattern.

13-16 mm SL) may occur (? at night) in upper 100-200 m (Fig. 6).

Clarke (1973) reported that in the central North Pacific (near Hawaii), adults apparently do not undertake diel migration from a day living depth of 490-690 m; but small juveniles were taken in the upper 100-200 m at night. Our data (Figs. 6, 7) confirm this: small specimens (< 20 mm SL) have been reported in the upper 100-200 m at night, while slightly larger specimens (19-29 mm SL) migrate only to the 230 m depth stratum from daytime living depths below 600 m.

Geographic distribution

Bolinichthys distofax may be locally common within its distributional range (Fig. 8). In the South Atlantic, it occurs mainly between 06°S-25°58'S (western sector) and between 06°S-15°45'S (eastern sector), with only two records to north of this region: at 02°26'N, 034°50'W (Hulley, 1981) and at 09°01'N, 059°04'W (MCZ 125404) (Nafpaktitis *et al.*, 1977). The following records of small specimens, held in collections as *B. supralateralis*, should be referred to *B. distofax* on the basis of their gill-raker counts: MCZ 123735: 1 specimen (14 mm SL), GR 5 + 1 + 9-10; MCZ 123736: 1 specimen (16 mm SL), GR 5 + 1 + 9-10; and ROM 27383: 3 specimens (29-32 mm SL), GR 5 + 1 + 10-11. Therefore, the distribution of the species in the Atlantic Ocean appears to be closely linked to the circulation of the southern gyre alone (see also Remarks below).

In the central North and South Pacific (Fig. 8), *Bolinichthys distofax* occurs between about 18°-32°N, 140°-160°W and 10°-13°S, 140°-150°W respectively, with several records at 03°30'N, 145°00'W (Hartmann and Clarke, 1975: tabs. 2, 4). In the western North Pacific it has been taken between about 16°-36°N, 122°-144°E; and in the western South Pacific between 0°-08°S, 170°-180°E. There are two additional records from the Solomon Sea at 08°03'S, 150°32'E (AM I.19740009) and at 13°50'S, 148°18'E in the Coral Sea, that is the first record from Australian waters (MCZ 91051: previously identified as *B. blacki*).

The species has never been recorded in the Indian Ocean (Fig. 8).

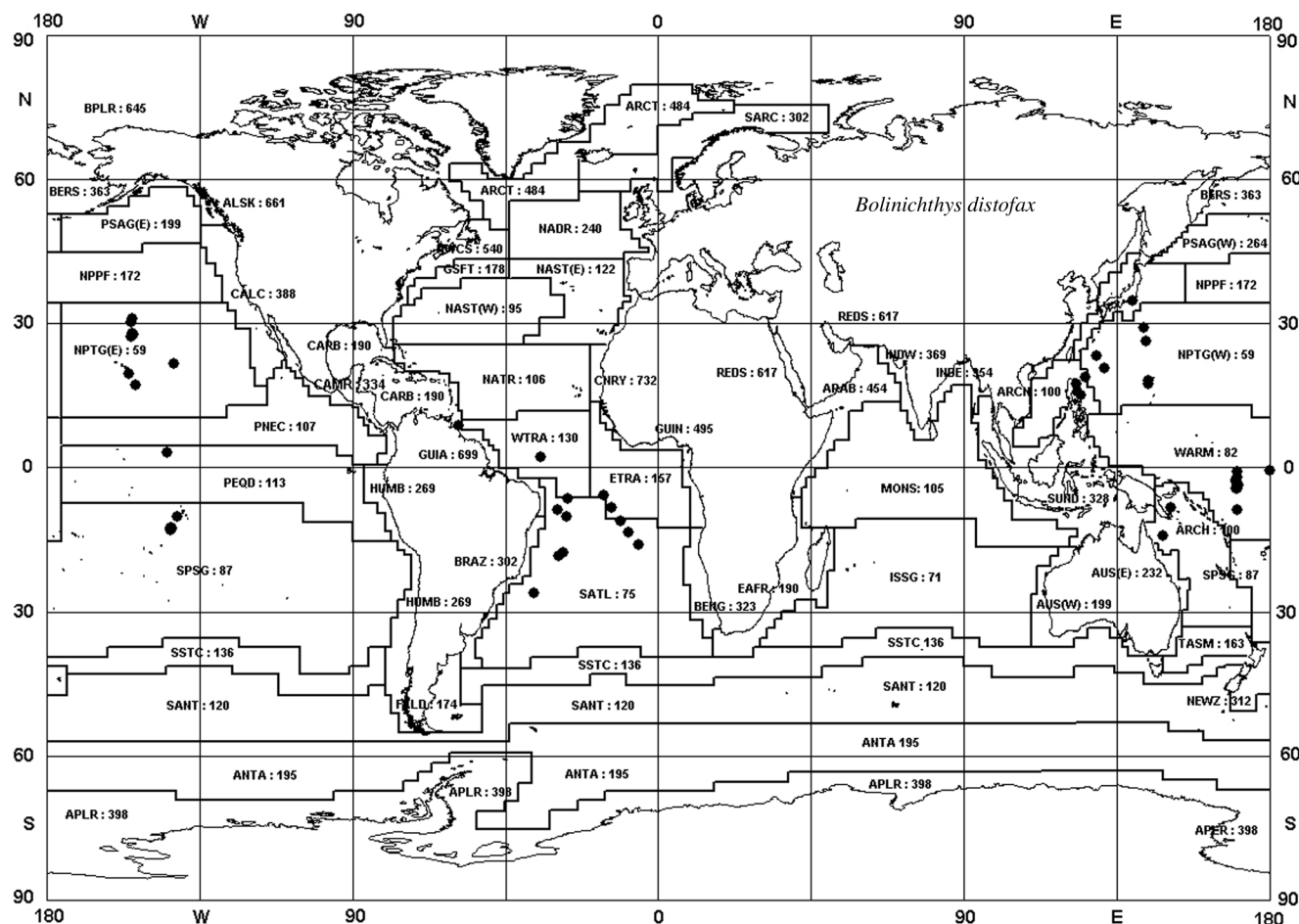


Figure 8. - *Bolinichthys distofax*. Geographic distribution in relation to Longhurst (1998) provinces. Numbers refer to primary productivity values ($\text{gCm}^{-2}\text{y}^{-1}$ - after Longhurst *et al.*, 1995).

Hulley (1981) suggested that the geographic distribution in both the Atlantic and Pacific shows a close relationship with the circulation of less-productive waters of the gyral systems of these oceans. The distribution of *B. distofax* in accordance with Longhurst's ecological provinces and annual primary production values ($\text{gmCm}^{-2}\text{y}^{-1}$) (Longhurst *et al.*, 1995; Longhurst, 1998) is given in figure 8. However, equally low primary production values ($< 106 \text{ gCm}^{-2}\text{y}^{-1}$) are also evident in the western North Atlantic Subtropical Gyral Province (NAST(W)), the North Atlantic Tropical Gyre Province (NATR), the Indian Monsoon Gyre Province (MONS) and Indian South Subtropical Gyre Province (ISSG), where the species has never been recorded (see above). Examination of the depths of the 5°C and 6°C isotherms suggests that warmer water is found at greater depths in the NAST(W), NATR, MONS and ISSG provinces than elsewhere. It may be that non-migrating *B. distofax* may not be able to fulfil energy requirements where both a more restricted food supply and a somewhat warmer environment are evident.

Remarks

The following specimens of *B. distofax* from the North Atlantic have been re-identified as *B. supralateralis*: CAS 56929: $17^{\circ}15'54''\text{N}$, $062^{\circ}16'48''\text{W}$ (2 specimens, 78.5 mm SL, GR 7 + 1 + 13; 84.4 mm SL, GR 6 + 1 + 12); CAS 61091: 18.45°N , 062.42°W (1 specimen, 81.0 mm, GR 6 + 1 + 12). It should be noted that the locality data for CAS 61091 has been incorrectly entered into the GBIF database. Five specimens reported as *B. distofax* (SIO 88-199: $25^{\circ}22.7'\text{N}$, $077^{\circ}55.7'\text{W}$) have been re-identified as *B. supralateralis* (2 specimens) and as *B. indicus* (3 specimens).

BOLINICHTHYS INDICUS (NAFPAKTITIS & NAFPAKTITIS, 1969) (Figs 9-17; Tabs I-IV)

Synonymy

Lepidophanes indicus Nafpaktitis & Nafpaktitis, 1969: 61, figs. 72, 74-75 ($22^{\circ}34'\text{S}$, $64^{\circ}55'\text{E}$). Holotype: MCZ 46314; 17

paratypes: MCZ 46315 (1 spec.), 46316 (1 spec.), 46317 (2 spec.), 46318 (2 spec.), 46319 (2 spec.), 46320 (8 spec.), LACM 30300 (1 spec.).

Myctophum (Lampanyctus) longipes (non Brauer, 1906): Brauer, 1906: 166, 236-237 (*partim*) (non 4 syntypes: ZMHU 17612 (2 spec.), 17613 (2 spec.); specimens from off Madeira and Gulf of Guinea only); Parr, 1928: 82 (*partim*); Fowler, 1936: 383, 387-388 (*partim*); Maul, 1948: 143; Albuquerque, 1954: 354.

Lampanyctus pyrsobolus longipes (non Brauer, 1906): Tåning, 1928:65 (*partim*).

Macrostoma longipes (non Brauer, 1906): Fowler, 1936: 1229 (*partim*).

Lampanyctus (Lepidophanes) pyrsobolus (non Alcock, 1890): Fraser-Brunner 1949: 1092 (*partim*).

Lampanyctus longipes: Beebe, 1937: 204; Beebe and van der Pyl, 1944: 81-82, fig. 14 (*partim*); Postel, 1959: 147.

Lepidophanes pyrsobolus (non Alcock, 1890): Bolin, 1959: 35-37 (*partim*); Briggs, 1960: 175 (*partim*); Bullis and Thompson, 1965: 29; Backus *et al.*, 1965: 145 (*partim*); Becker, 1967b: 119 (*partim*); 1967a: 180 (*partim*); Harrison, 1967: 91, fig. 10; Backus *et al.*, 1969: 95, 100; Badcock, 1970: 1027, fig. 10; Tortonese, 1972: 24.

Lepidophanes indicus: Gibbs *et al.*, 1971: 115-116, 125, 133; Hulley, 1972a: 225-226; Kotthaus, 1972a: 15 (author's correction), 23-27, fig. 89 (otoliths) (*partim*); Krefft and Becker, 1973: 191; Eschmeyer, 2008.

Bolinichthys indicus: Paxton, 1972: 47; 1979: 6-7; Johnson, 1975: 53, 55; 1982: 185; Krefft, 1973: 318; Jahn and Backus, 1976: 228, tab. 3, fig. 6; Badcock and Merrett, 1976: 42, 45, 51, fig. 21; Nafpaktitis *et al.*, 1977: 238-241, figs. 167-168; Backus *et al.*, 1977: 267, 274-275, 277; Krueger *et al.*, 1977: 783; Nafpaktitis, 1978a: 6; Quéro, 1977: 74; Hulley, 1981: 227-230, figs. 105b, 106; 1984a: 435, fig.; 1984b: 67, fig. 4; 1986b: tab. 7; 1989: 51; 1990: 401; 1992: tab. 2; Becker, 1983: 215, figs. 50 (d), 99 (3); McKelvie, 1985b: tab. 3; 1985a: 129, tab. 1; Karnella, 1987: 58-61, tabs. 30-32; Gartner *et al.*, 1989: 557, 560, tabs. 1-2, 4; Paxton *et al.*, 1989: 254; Iwami and Kubodera, 1990: 68, tabs. 2-3; Hulley and Duhamel, 1990: tab. 2; van der Spoel and Bleeker, 1991: 96, tab. I, fig. 1; Brooks and Saenger, 1991: tab. 2, fig. 9; Craddock *et al.*, 1992: S214, tabs. 1-2, 5-6; Smale *et al.*, 1995: 42, pl. 17; Linkowski, 1996: tab. 1; Duhamel, 1997: tab. 1; Paxton and Hulley, 1999: 1962; Olivar *et al.*, 1999: 110, tab. 1; Moser and Watson, 2001: tabs. 1-3; Craddock and Hartel, 2002: 950; Moore *et al.*, 2003: 198; Brito *et al.*, 2002: 113; Nellen and Ruseler, 2004: tab. 1; Pusch *et al.*, 2004: Tabs. 2, 4; Hoese *et al.*, 2006: 510; Herring, 2007: tab. 4; Eschmeyer, 2008; Hulley and Paxton, in press.

Remarks on synonyms

Of the 8 Indian Ocean type-locality records for *Myctophum (Lampanyctus) longipes* originally listed by Brauer (1906), one is from further south than 20°S ('Valdivia' Stn. 175: 26°03'06"S, 93°14'09"E). It might therefore be referable to *B. indicus* by virtue of its geographic distribution

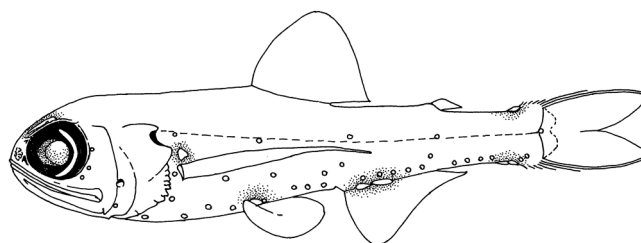


Figure 9. - *Bolinichthys indicus*. SL 31 mm (after Nafpaktitis *et al.*, 1977).

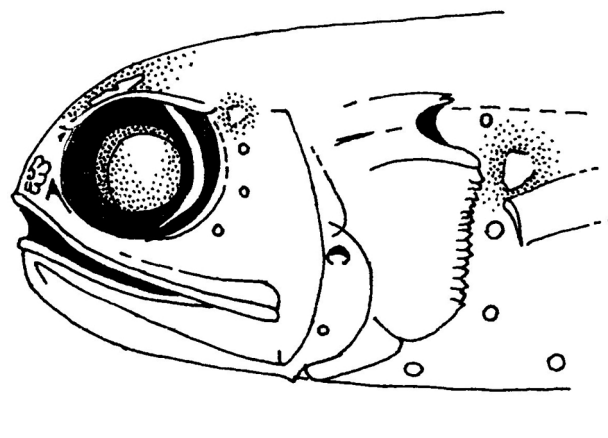


Figure 10. - *Bolinichthys indicus*. Lateral view of head (ISH 2595-1979, SL 44.4 mm). Scale = 10 mm.

(see below; and compare Nafpaktitis and Nafpaktitis, 1969: fig. 72). However this specimen is no longer extant; other than the four specimens in two lots of *B. longipes* syntypes (ZMB 17612: 'Valdivia' Stn. 215; ZMB 17613: 'Valdivia' Stn. 217) no other specimens of the series could be found in the in the ZMB Collection (Dr. Peter Bartsch, pers. comm.).

Bolin's (1959) count of GR 3 + 1 + 11 confirms that *B. indicus* may be one of the species incorporated in his synonymy of *B. pyrsobolus* (see Tab. IV).

Meristics

D 13 (12-14); A 13 (12-15); P 13 (12-14); AO 6 (4-7) + 4 (2-5), total 10 (8-12); GR 4 (3-5) + 1 + 11 (9-12), total 16 (14-18).

Description

Eye large, aphakic space present; crescent of white tissue on posterior half of iris. Large re-curved preopercular spine absent. Posterodorsal margin of operculum anteriorly concave, distance between posterior cusps about equal to base of pectoral fin; subopercle serrate; interopercle smooth (Figs. 9-10). Origin of dorsal fin about on, or slightly behind vertical through outer base of pelvic fin; origin of anal fin behind vertical through posterior end of base of dorsal fin; pectoral fins long, reaching to SAO₃; pelvic fins reaching to

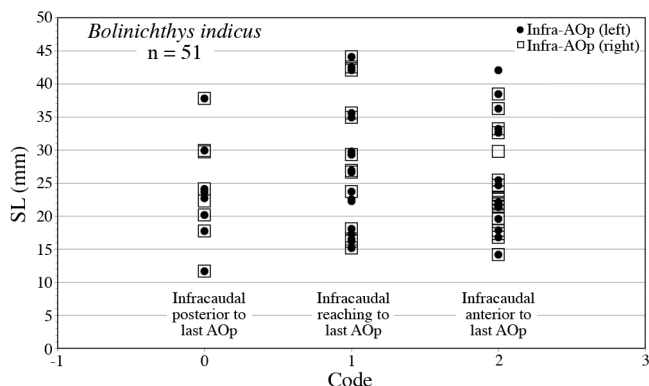


Figure 11. - *Bolinichthys indicus*. Variation of anterior extension of infracaudal luminous tissue with standard length.

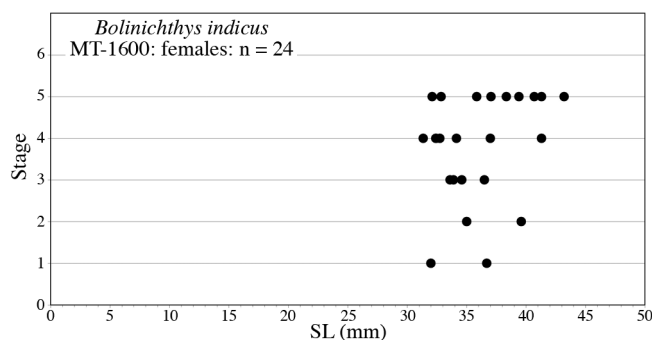


Figure 12. - *Bolinichthys indicus*. Relationship of sexual maturity to standard length (SL).

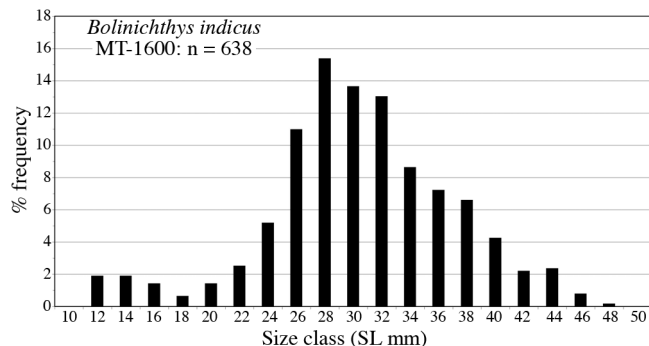


Figure 13. - *Bolinichthys indicus*. Length-frequency histogram of specimens from MT-1600 samples.

anus; adipose origin in advance of end of base of anal fin.

Vn at anterior border of eye, between nasal rosette and anterior margin of pupil. Three small post-ocular photophores. Op₁ below level of posterior angle of mouth, just above ventral margin of posterior flange of preopercle; Op₂ larger, just below level of ventral margin of orbit. PLO at, immediately above, or just below lateral line. PVO₁ directly under, slightly in advance, or just behind PVO₂, which is in front of middle of base of pectoral fin. 5 PO; with PO₃ raised above line through centres of PO₁-PO₂; with PO₄ dorsal to level of PVO₁, and nearer to PO₅ than PO₃; and with PO₅ in front of outer pelvic base. VLO at, or less than 1 photo-

phore diameter below lateral line, well posterior to vertical through outer pelvic base. 5 VO (rarely 4); with VO₂ highly and abruptly elevated, at or slightly above line connecting PO₄-SAO₁; and VO₃-VO₅ on a straight descending line. SAO₁ immediately in front of, or slightly posterior to vertical through VO₅, below level of PO₄; SAO₂ on, or slightly behind vertical through origin of anal fin, and nearer to SAO₁ than SAO₃; and with SAO₃ at, or just above lateral line, posterior to vertical through origin of anal fin. AO series divided into AOa and AOp with AOa₁ and last AOa level (AOa₁ sometimes depressed); 4 (3-5) AOp, evenly spaced and all posterior to end of anal fin, sometimes varying in number on opposite sides of trunk (Fig. 11). 2 Pol (by definition); with Pol₁ elevated above AOa series, about on vertical through middle of adipose fin; and with Pol₂ at lateral line, on or little behind vertical through base of adipose fin. 2+1 Prc; with Prc₂ about 1-1.5 photophore diameters posterodorsad to Prc₁; and with Prc₃ well behind Prc₂ and above level of lateral line. Minute secondary photophores on trunk. Supracaudal organ consisting of 1-2 luminous, scale-like patches; infracaudal organ consisting of 2-4 luminous, scale-like patches, extending anteriorly from procurrent caudal rays to behind, at, or anterior to level of last AOp (Fig. 11); forward extension apparently independent of size, but loosely correlated with the number of AOp photophores; length and development of infracaudal tissue apparently sexually dimorphic, being longer and more dense in males than in females. 2-3 pairs (sometimes coalesced) of patches of luminous tissue on top of head, anterior pair being largest, and each patch usually associated with small, black-backed secondary photophore; patches sexually dimorphic, being denser and more developed and circumscribed in males than in females. A patch of luminous tissue present between upper base of pectoral fin and PLO; a single, scale-like patch of luminous tissue at base of pelvic fin. 0-2 luminous patches or spots along base of dorsal fin; 2-3 (rarely 4) elongate, luminous patches along base of anal fin.

Size and maturation

Maximum size to 47 mm SL; no apparent sexual dimorphism in size (Karnella, 1987); females sexually mature from about 31 mm SL (Fig. 12). Near Bermuda, spawning occurs from mid-spring to late fall, with a peak in late summer (Karnella, 1987).

Karnella's (1987) observation that the species apparently has a one-year life-cycle is supported by the fact that the size ranges of specimens taken with MT-1600 nets are similar to those taken with 10' IKMT nets (Figs. 13-16; Karnella 1987: tab. 32). Further, a single year-class seems to be evident in the MT-1600 data sets (Fig. 13). However, frequency data for size classes below 18 mm should be treated with reservation, since the MT-1600 is a poor sampler of small fishes, even when a cod-end liner is fitted to the net.

Depth distribution

Bolinichthys indicus is an oceanic, mesopelagic species, occurring in depths of 425-900 m (day) and 25-300 m (night), with a reported maximum abundance at 600-700 m (day) and 50-150 m (night) (Karnella, 1987; Moore *et al.*, 2003). Near Bermuda, it undertakes diel migration in all seasons, but 34% (late summer) and 8% (winter) of the population remain at depth during the night; non-migrants include postlarvae and small juveniles. Upward migration commences about 2-3 hours (late summer) and 1-2 hours (winter) before sunset at rates of 129-186 m.hr⁻¹ (late summer -smaller fish migrate more slowly) and about 200 m.hr⁻¹ (winter). Day depths are reached 2 hours (late summer) and 1.5 hours (winter) after sunrise during downward migration, at rates of 180-260 m.hr⁻¹ (late summer-smaller fish migrate more slowly) and 250 m.hr⁻¹ (winter) (Karnella, 1987).

Although pooled data suggest that there is no size stratification with either fishing depth or with latitude (Figs. 14-16), Karnella (1987) reported that near Bermuda, adults were not found in the upper 100 m of the water column in winter, and only post-larvae were taken in the upper 50 m in late summer.

Geographic distribution

Bolinichthys indicus is said to be a Bisubtropical Pattern species (Hulley, 1981) or Bipolar Subtropical Pattern species (Karnella, 1987) (Fig. 17). It has been reported from the eastern North Atlantic (east 30°E) between about 54°N and 0°, with two records from the Gulf of Guinea at 02°57'S, 08°05'E (MCZ 124552: 3 specimens) and 02°54'S, 08°06'E (MCZ 124553: 2 specimens; MCZ 155050: 1 specimen), but is absent from the Mediterranean Sea. In the western North Atlantic it occurs between 42°N and 0°, with a northern extension in Gulf Stream to 53°N (east of 40°W), but is absent in Gulf of Mexico and Caribbean, and apparently less abundant in South Sargasso Sea (Backus *et al.*, 1969). In the western South Atlantic, *B. indicus* has been taken between about 18°S and southern STC, but is absent from southern gyral waters between 0°-18°S; the paucity of records between 18°S and 28°S is due to the discarding of material (identified only as *B. pyrsobolus*) during the 1966-1971 WH cruises (see Hulley, 1981). The species has not been recorded off the southern Brazil slope (22°-34°S) (dos Santos, 2003). In the eastern South Atlantic, it has been taken between 15°S and southern STC, but is absent in the upwelled waters of Benguela region (although it may be present in Agulhas rings: see Hulley, 1981). In the Indian Ocean it has been taken between about 15°S and the STC. It is absent in Mozambique Channel, but is present in Agulhas Current region to at least 34°S. There are two records off Western Australia (30°-34°S). Those records reported for the northern Indian Ocean and south western Pacific Ocean may be erroneous (see Remarks).

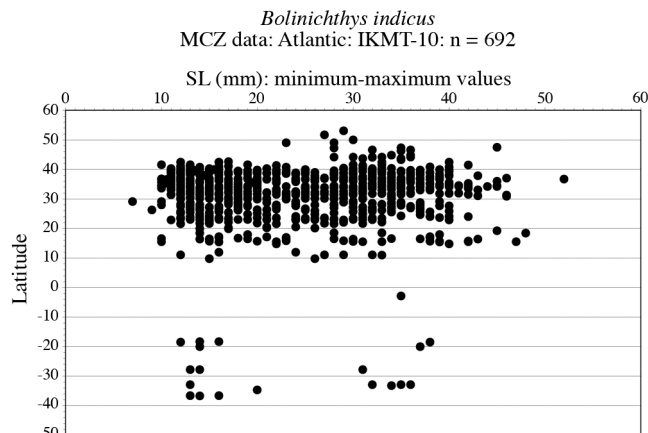


Figure 14. - *Bolinichthys indicus*. Variation of standard length (SL) with latitude.

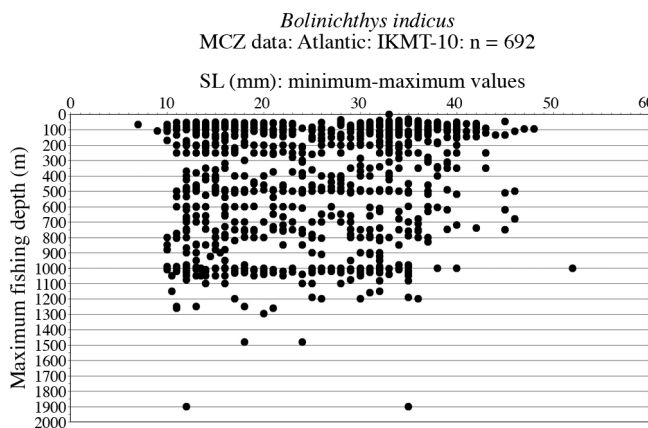


Figure 15. - *Bolinichthys indicus*. Variation of standard length (SL) with maximum fishing depth of IKMT-10 haul.

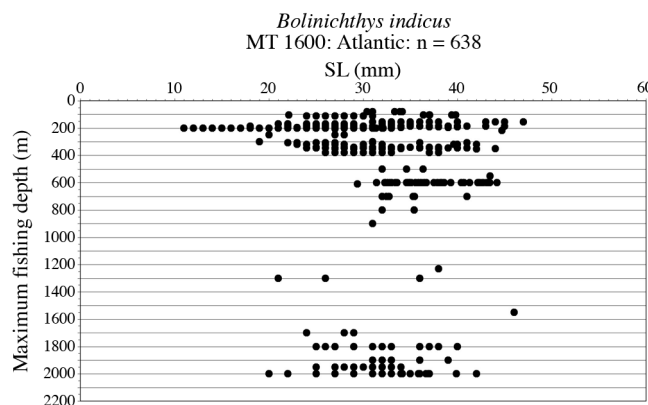


Figure 16. - *Bolinichthys indicus*. Variation of standard length (SL) with maximum fishing depth of MT-1600 haul.

Since the distribution of *B. indicus* is essentially the “mirror-image” of its closely-related congener *B. longipes* (Figs. 17, 28), with the boundary limit in the Indian Ocean corresponding to the well-developed hydro-chemical front at 10°S (Wyrтки, 1971; 1973a; Worthington, 1981; Pickard

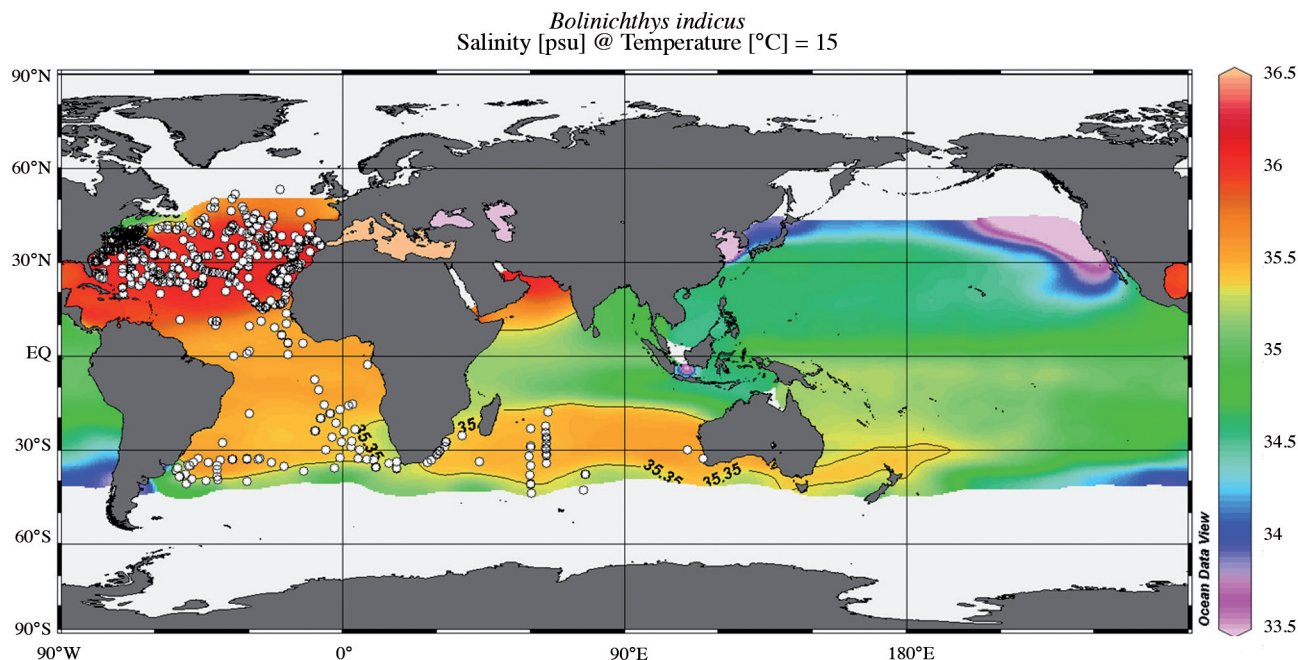


Figure 17. - *Bolinichthys indicus*. Geographic distribution in relation to salinity at 15°C.

and Emery, 1992), further discussion of the distribution in relation to water mass structure is dealt with under *B. longipes* (see below).

Remarks

The identification of three small specimens (ca 16-24 mm SL) from the Somali Upwelling tongue (MCZ 124793: 11°54'N, 60°46'E) as *B. indicus* should be treated with reservation. The largest specimen has GR 5+1+10, which is more typical of *B. longipes* than *B. indicus* (Tabs. IV) and the locality is well to the north of the proposed limit.

Three specimens taken south-west of Sri Lanka (FM 71915: 04°24'00"N, 073°48'00"E: 23-52 mm SL) prove on re-examination to be *B. pyrsobolus* on the basis of the following characters: no small post-ocular photophores and VLO midway between lateral line and outer pelvic base; VO₂ highly elevated touching line PO₄-SAO₁; VO₂-VO_{4.5} angulate; ventral edge of interopercle smooth; GRt count > 14; 3-5 luminous patches above anal base; infracaudal luminous tissue reaching to ca. AOp₂-AOp₃.

Two slightly damaged specimens from the Coral Sea tentatively identified as *B. (?) indicus* (MCZ 91053: 14°13'S, 148°38'E: 31-32 mm SL: GR 5+1+10-12) should be referred to *B. longipes*.

Ten specimens (15-17 mm SL) reported from 02°57'S, 099°36'E (ZMUC P 2363747-2363756) should also be treated with reservation. At least one of the specimens can be referred to *B. pyrsobolus*, as it has no post-ocular photophores and the VLO is midway between lateral line and outer pelvic base (Dr. Jørgen Nielsen, pers. comm.). These speci-

mens are not included in the point distribution data-sets.

The following SIO specimens, identified as *B. indicus*, have been re-identified on the basis of morphometric data supplied by Dr. Cindy Klapedlo (pers. comm.). They are not included in the point distribution data-sets: SIO 61-33: 10°44.5'S, 098°44.1'E: 2 of 2 (15-30 mm) = *B. photothorax* and *B. sp.*; SIO 61-35: 14°57.9'S, 070°02.0'E: 2 of 2 (16-22 mm) = *B. sp.*; SIO 61-650: 15°39.5'N, 111°49.5'E: 2 of 2 (10-11 mm) = *B. sp.*; SIO 69-20: 06°54.2'N, 114°47.9'E: 3 of 3 (24-26 mm) = *B. pyrsobolus*; and SIO 69-27: 25°27.5'S, 038°11.0'E: 1 of 4 (17 mm) = ? *B. supralateralis*.

BOLINICHTHYS LONGIPES (BRAUER, 1906)

(Figs 18-28, 30; Tabs I-IV)

Synonymy

Myctophum (Lampanyctus) longipes Brauer, 1906: 236 (only tropical Indian Ocean localities). Syntypes: ZMB 17612 (2 spec.), 17613 (2 spec.), Krefft and Becker, 1973: 191.

Myctophum (Lampanyctus) longipes: Eschmeyer, 2008.

? *Lampanyctus joubini* Angel & Verrier, 1931: 127 (01°16'S, 138°55'E). Holotype: not found at MOM or MNHN.

Lampanyctus joubini: Eschmeyer, 2008.

? *Macrostoma grayi* Fowler, 1938: 190-191, fig. 15 (40 miles south of Christmas Island). Holotype: ANSP 68366.

Macrostoma grayi: Eschmeyer, 2008.

Lampanyctus fraser-brunneri Bolin, 1946: 150-151, fig. 5 (05°56'N, 76°22'E). Holotype: ZSI, lost (Menon and Rao, 1971); ZSI F7336/2 found; paratype: SU 40376m (1 spec.); Eschmeyer, 2008.

Lampanyctus longipes: Misra, 1952: 419.

Lepidophanes pyrsobolus: Briggs, 1960: 175 (*partim*).

Lepidophanes longipes: Nafpaktitis and Nafpaktitis, 1969: 58, figs. 71-72; Kotthaus, 1972b: 33-34, figs. 279-285; Legand *et al.*, 1972: 305, 317-318.

Bolinichthys longipes: Paxton, 1972: 6, 47; 1979: 6; Clarke, 1973: 421-422, fig 10; 1980: 629, tab. 2, figs. 1-4; Hartmann and Clarke, 1975: 635, tabs. 3-4; Wisner, 1976: 204-205, tabs. 40-41; figs. 191-192; Loeb, 1979a: tabs. 2, 7; 1980: tabs. 4-6, 8; 1986: fig. 4; Gjøsæter, 1981: 220-222, tab. 1; Brandt, 1981: tab. 2; Neighbors and Nafpaktitis, 1982: 208, tabs. 1-2; Becker, 1983: 215, figs. 50 (v), 99 (1); Barnett, 1983: tab. 2; 1984: 207, tabs. 3-4; Willis, 1984: tab. 2; Gartner *et al.*, 1987: tab. 9; Kubota *et al.*, 1989: tabs. 2-3; Paxton *et al.*, 1989: 254-255; Childress *et al.*, 1990: tab. 1; Parin *et al.*, 1990a: 202; 1990b: 45; 1995: 1320; Dalpadado and Gjøsæter, 1993: 161, 164, tab. 1, Appendix 1; Shinohara *et al.*, 1996: 164; 2005: 411; Tsarin, 1996: tabs. 1-2; Shinohara and Matsuura, 1997: 285; Butler *et al.*, 1997: 18, tab. 3, fig. 22; Hulley and Paxton, 1999: 1962; 2000b: 593; Rivaton and Bourret, 1999: 238, pl. 110 (1-9); Nakabo, 2000: 378, fig.; 2002: 378, fig.; Wang and Chen, 2001: 110, fig. 29, tabs. 2-3; Mundy, 2005: 212; Hoeser *et al.*, 2006: 511; Herring, 2007: tab. 4; Sassa *et al.*, 2007: 2184, tabs. 1, 2; Eschmeyer, 2008.-

Bolinichthys longipes: Fujita, 1990: 311, fig. 130, tabs. 2-5, 3-6.

Remarks on synonyms

Lampanyctus joubini Angel & Verrier, 1931, which was described on the basis of a single specimen (Station 3766: 01°16'S, 138°55'E), is confirmed as a junior synonym of *B. longipes*, by virtue of the fact that there are 3 post-ocular photophores; luminous tissue is absent both above the pectoral base and at PVO₁; VLO is at the lateral line; a luminous scale is present at the pelvic fin base; and the infracaudal luminous tissue does not reach the last AOp. The type material is lost (Paxton, 1979).

Macrostoma grayi Fowler, 1938 is also a junior synonym of *B. longipes*. Despite the fact that the VLO is about two diameters below the lateral line, there are 3 post-ocular photophores; a single large, luminous patch is present at the anterior base of the anal fin; the PVO₁-PVO₂ distance is greater than Op₁-Op₂; and GRt = 17.

Bolin (1946) based his description of *Lampanyctus fraserbrunneri* on specimens from the northern Indian Ocean (05°56'N, 076°22'E). He indicated that the species was closely related to other species with post-ocular photophores, but could be distinguished from *Lampanyctus* (= *Bolinichthys*) *longipes* by the possession of a Vn, and from *Lampanyctus* (= *Bolinichthys*) *photothorax* by mainly lacking luminous tissue above the pectoral base and below PVO₁. While a Vn is present in all members of the genus, the absence of a luminous scale above the pectoral base; a GR 4 + 1 + 11 count; and the position of the type locality, confirm that

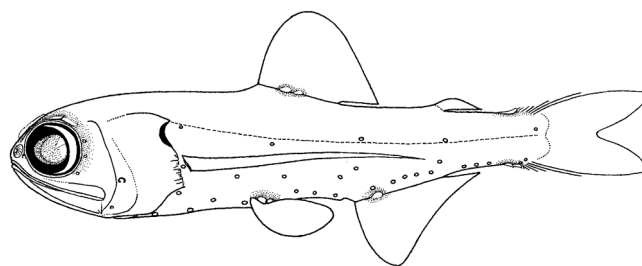


Figure 18. - *Bolinichthys longipes*. SL 42.5 mm (after Nafpaktitis and Nafpaktitis, 1969).

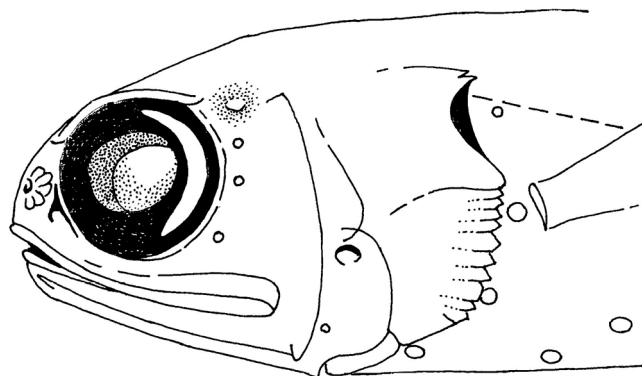


Figure 19. - *Bolinichthys longipes*. Lateral view of head and supra-ocular luminous tissue (MNHN 1991-1830: SL 31.7 mm). Scale = 10 mm.

L. fraserbrunneri is a junior synonym of *B. longipes*.

Brauer's (1906) syntypes (ZMB 17612: 17.8 mm, 14.8 mm SL; ZMB 17613: 11 mm, 12 mm SL) are in poor condition, and the largest has missing opercula on both sides. Since these extant types do not show many of the distinguishing characters, and since there appears to be no problem with nomenclatural instability in the species, a lectotype for *Myctophum* (*Lampanyctus*) *longipes* has not been designated.

Meristics

D 13 (12-14); A 14 (13-15); P 12 (13); AO 5 (4-6) + 4 (3-5), total 9 (7-10); GR 4 (3-5) + 1 + 10 (9-12), total 15-16 (13-18).

Description

Eye large, aphakic space present; crescent of white tissue on posterior half of iris. Large re-curved preopercular spine absent. Posterodorsal margin of operculum anteriorly concave, distance between posterior cusps about twice length of base of pectoral fin; subopercle serrate; interopercle smooth (Figs. 18-19). Origin of dorsal fin about on, or slightly behind vertical through outer base of pelvic fin; origin of anal fin behind vertical through posterior end of base

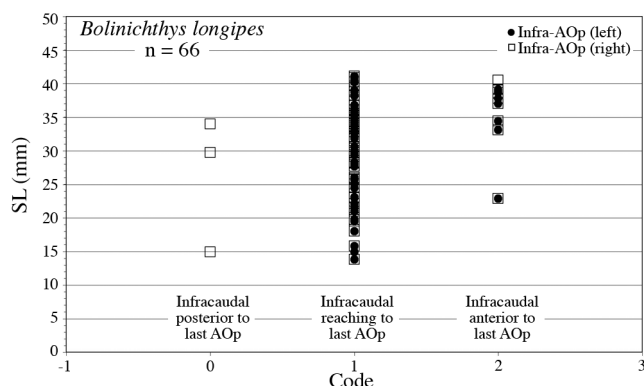


Figure 20. - *Bolinichthys longipes*. Variation of anterior extension of infracaudal luminous tissue with standard length.

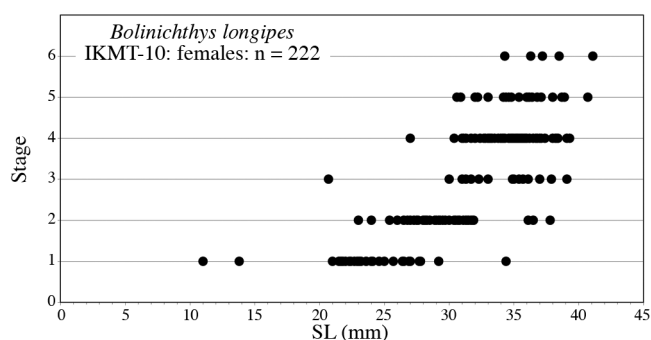


Figure 21. - *Bolinichthys longipes*. Relationship of sexual maturity to standard length (SL).

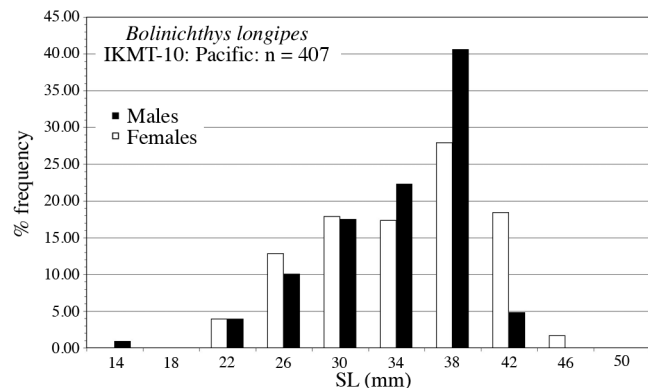


Figure 22. - *Bolinichthys longipes*. Length-frequency histograms for males and females.

of dorsal fin; pectoral fins long, reaching to below adipose fin; pelvic fins reaching to anus; adipose origin in advance of end of base of anal fin.

Vn at anterior border of eye, between nasal rosette and anterior edge of pupil. Three small post-ocular photophores. Op₁ below level of posterior angle of mouth, just above ventral margin of posterior flange of preopercle; Op₂ larger, at about level of ventral margin of orbit. PLO in contact with lateral line. PVO₁ slightly in advance of PVO₂, which is in front of middle of base of pectoral fin. 5 PO; with PO₃ raised

above line through centres of PO₁-PO₂; with PO₄ dorsal to level of PVO₁, and nearer to PO₅ than PO₃; and with PO₅ in front of outer pelvic base. VLO at, or less than 1 photophore diameter below lateral line, on or posterior to vertical through outer pelvic base. 5 VO; with VO₂ highly and abruptly elevated, at or slightly above line connecting PO₄-SAO₁; and with VO₃-VO₅ in a straight descending line. SAO₁ slightly posterior to vertical through VO₅, at about level of PO₄; with SAO₂ on, or slightly behind vertical through origin of anal fin, closer to SAO₁ than SAO₃; and with SAO₃ at, or just above lateral line, posterior to vertical through origin of anal fin. AO series divided into AOa and AOp, with AOa₁ and last AOa level; AOp evenly spaced and all posterior to end of anal fin. 2 Pol (by definition), with Pol₁ elevated above AOa series, about on vertical through middle of adipose fin; and with Pol₂ at, or just above lateral line, on or little behind vertical through base of adipose fin. 2+1 Prc; with Prc₂ about 1 photophore diameter posterodorsad to Prc₁; and with Prc₃ well behind Prc₂ and above level of lateral line. Minute secondary photophores on trunk. Supracaudal luminous tissue consisting of 1-2 luminous, scale-like patches; infracaudal organ consisting of 2-3 luminous, scale-like patches, extending anteriorly from procurent caudal rays to behind level of last AOp, or to level of last AOp, or anterior to level of last AOp (Figs. 18, 20); forward extension apparently independent of size, but loosely correlated with the number of AOp photophores; length and development of infracaudal patches apparently sexually dimorphic, being longer and more dense in males than in females. 2-3 pairs (sometimes coalesced) of patches of luminous tissue on top of head, the anterior pair being the largest and each patch usually associated with a small, black-backed secondary photophore; patches sexually dimorphic, being denser and more developed and circumscribed in males than in females. A patch of luminous tissue between upper base of pectoral fin and PLO absent; a single, scale-like patch of luminous tissue at base of pelvic fin. 2-3 luminous patches along base of dorsal fin; a single (sometimes 2) elongate, luminous patch(es) at base of anal fin.

Size and maturation

Maximum size to 55 mm SL (Becker, 1983), but largest of 2772 specimens examined in present study 43 mm SL; females sexually mature from about 31 mm SL (Fig. 21); size-frequency distributions suggest a one year life-cycle (Fig. 22). In the Central Pacific, there is no apparent sexual dimorphism in size (Fig. 22). Here, mature females (Stages IV and V) have been taken in February, March, June, July, September, October, November and December, suggesting that reproduction takes place throughout the year. Near Hawaii, spawning occurs mainly in spring and summer (Clarke, 1973).

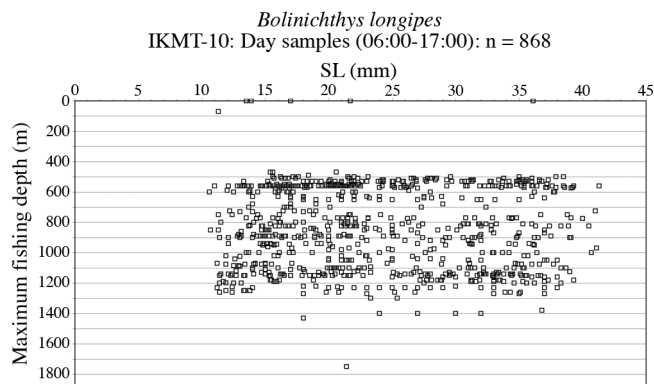


Figure 23. - *Bolinichthys longipes*. Variation of standard length (SL) with maximum fishing depth of day haul.

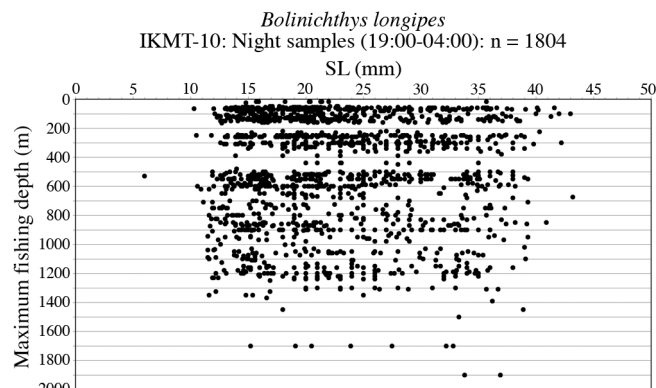


Figure 24. - *Bolinichthys longipes*. Variation of standard length (SL) with maximum fishing depth of night haul.

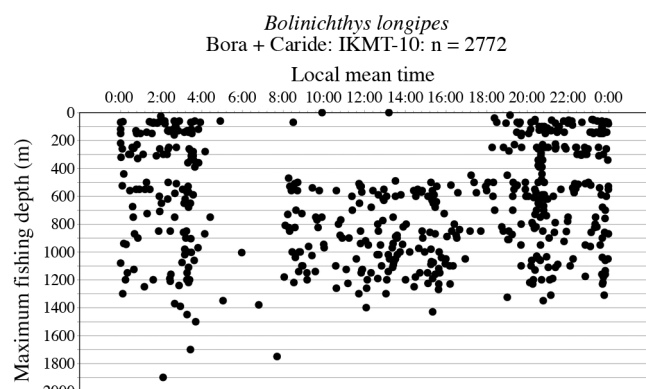


Figure 25. - *Bolinichthys longipes*. Diel migration pattern.

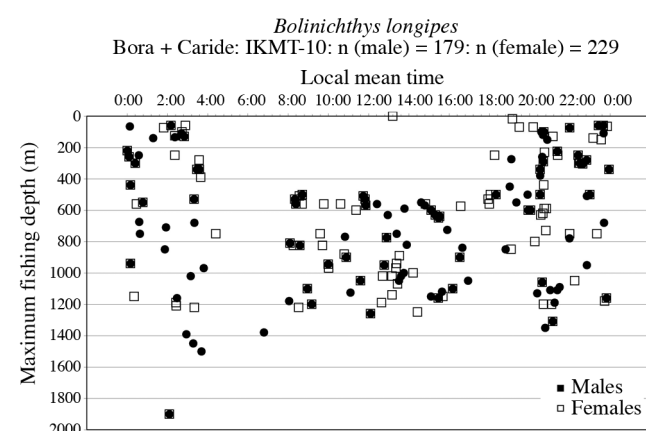


Figure 26. - *Bolinichthys longipes*. Diel migration patterns in males and females.

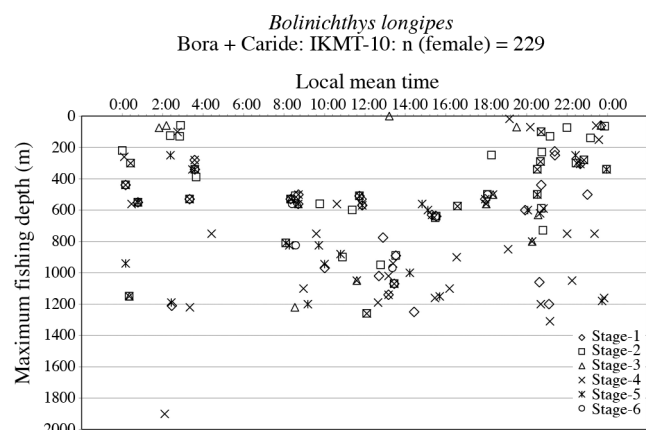


Figure 27. - *Bolinichthys longipes*. Diel migration patterns in staged females.

Depth distribution

Bolinichthys longipes is an oceanic, mesopelagic species. Off Hawaii, it has been taken between 500-725 m (day) and 50-150 m (night) (Mundy, 2005). All size classes exhibit diel migration, with peak abundances between 75-100 m (night). Size-stratification with depth during the day, and probably also at night has been reported near Hawaii (Clarke, 1973). In the Central Pacific, there is also no size-stratification with

depth, during day (06:00-17:00) or night (19:00-04:00), with the size of specimens from both day samples (below about 500 m) and night samples (upper 50 m) ranging between about 10-41 mm SL (Figs. 23-24). Larvae are relatively more abundant in upper 25 m (night), again with some evidence of size-stratification with depth (Loeb, 1979a, 1979b, 1980).

In the equatorial Central Pacific, *B. longipes* is generally not found in the upper 500 m of the water column during day (06:00-17:00), although occasionally, small specimens (13-21 mm SL) were taken during this photo-period (Fig. 23). The whole population appears to migrate within the crepuscular period into the upper 50 m at night (19:00-04:00) (Figs. 24-25). These data should be viewed against the sampling intensity at various depths/times during the series of *Bora* and *Caride* cruises (Fig. 2). The migratory behaviour pattern appears to be similar for males and females (Fig. 26). There is no evidence of depth-stratification by size (Figs. 23-24), by sex, or by female maturity stage (Figs. 26-27).

Geographic distribution

Bolinichthys longipes is a warm-water species, generally occurring in the Equatorial and Central Water masses

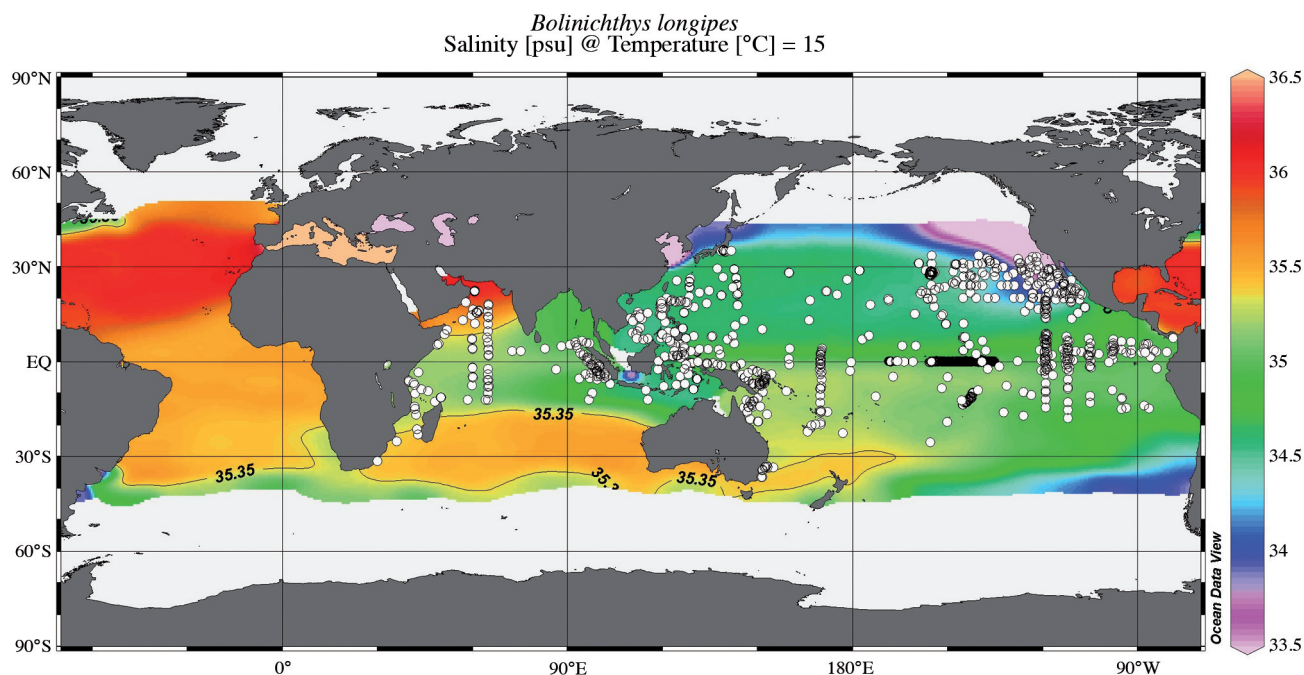


Figure 28. - *Bolinichthys longipes*. Geographic distribution in relation to salinity at 15°C.

of the Indo-Pacific (Fig. 28) (Hartmann and Weikert, 1969; Hartmann and Clarke, 1975). In the Indian Ocean, it has been taken from the Arabian Sea (22°18'N, 60°46'E: MCZ 151774) to about 12°S. Museum records from further south in the Mozambique Channel (23°11'S, 42°54'E: ZMUC P 2365621-2365624) and Agulhas Current (31°33'S, 30°07'E (ZMUC P 2373164- 2373175) (see Remarks below). It has apparently never been taken within the Bay of Bengal, the syntype being at 07°1'2"N, 85°56'5"E ('Valdivia' Stn. 215) at the southern border. The species occurs in South-East Asian Seas (South China Sea, Celebes Sea, Molucca Sea, Banda Sea, and Arafura Sea) and in the western Pacific between 30°N-20°S; and has been found north to 35°N in the Kuroshio Current, and south to about 37°S in the East Australian eddy system (Fig. 28). In the central and eastern Pacific, *B. longipes* has been taken between about 34°N-20°S. Morphologically distinguishable populations have apparently been recognized within the North Central Pacific, Central Equatorial Pacific and South Central Pacific regions (Barnett, 1983; 1984). However, the basis for the recognition of these populations was unspecified.

In overview, the distribution of *B. longipes* is basically the "mirror-image" of its closely-related congener *B. indicus* (Figs. 17, 28). Its southern boundary limit in the Indian Ocean corresponds to the hydro-chemical front developed at about 10°S (Wyrski, 1971; 1973a; 1973b; Worthington, 1981). A similar boundary limit at 10°S has also been reported for a number of other diverse marine groups, e.g. tunas (Suda, 1973); melamphaeids and myctophids (Cohen,

1973); stomiatoid fishes (Gibbs Jr. and Hurwitz, 1967); evermannellids (Johnson, 1982); foramenifera, hydromedusa, copepods, euphausiids, chaetognaths (Nair, 1977; Rao, 1979; Nair and Madhupratap, 1984).

In fact, this front is inclined from 100 m depth at 10°-12°S to 800-1000 m at 16-20°S, and is less pronounced near Australia and NW Madagascar because of meridional circulation (Wyrski, 1973a; Pickard and Emery, 1992). Subsurface water to the north of the front has a lower O₂-concentration and higher nutrient level than subsurface water to the south of the front (Wyrski, 1973a; New *et al.*, 2005). The front is composed of an inflow jet of low salinity Australasian Mediterranean Water (Tomczak and Godfrey, 2002), which is entrained in the westward flowing South Equatorial Current, and which bifurcates north and south on approaching Madagascar (You and Tomczak, 1993). The jet demarcates the boundary between Indian Equatorial Water to the north and South Indian Central Water to the south. The latter is not only identical in hydro-chemical properties to both South Atlantic Central Water and Western South Pacific Central Water (Tomczak and Godfrey, 2002), but it appears that there is a significant interchange of South Atlantic Central Water into the Indian Ocean via a route to the south of the Agulhas Return Current (Gordon *et al.*, 1992).

While distributional point data for *B. longipes* and *B. indicus* in the Indian Ocean correlate fairly well with O₂-concentrations, temperatures and salinities below 50 m, these correlations are not as obvious in the Atlantic and Pacific oceans. However, exploration of the data sets in rela-

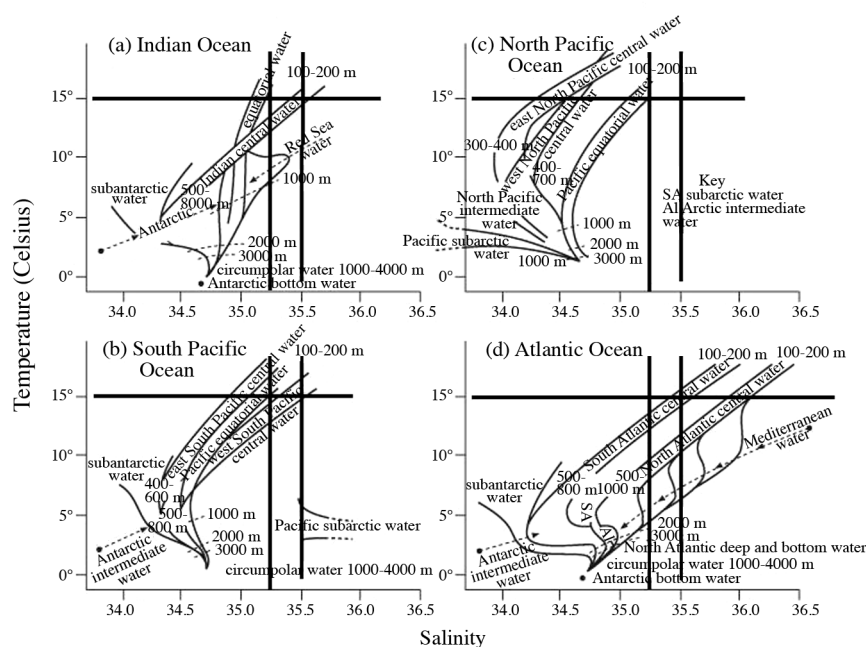


Figure 29. - T-S plots of water masses in various ocean basins (after Tolmazin, 1985).

tion to the annual mean salinity values at 15°C suggests a much more robust global correlation, with the distributions of the two species being best demarcated by the 35.35 and 35.50 psu isohalines at 15°C (Figs. 17, 28), except in the Arabian Sea and Red Sea Outflow regions.

The absence of *B. indicus* from off the south-east coast of Australia, off New Zealand (North Island) and in the south-west Pacific (ca. 30°S, 180°E), where these hydrographic parameters are matched, should be noted. However, a west-to-east distribution from the south-east Indian Ocean to the south-west Pacific Ocean seems unlikely, as *B. indicus* has never been reported from the Great Australian Bight, where the 35.35 psu isohaline runs close to the continental slope and shelf break.

The presence of *B. longipes* in the southern Mozambique Channel and along the east coasts of Mozambique and South Africa may be ascribed to the presence of less saline water, which is circulated to these regions by the meridional flow of the South Equatorial Current as it strikes the African coast. The occurrence of the species in the Red Sea and Arabian Sea Outflow regions requires additional, more detailed sampling and investigation, because its presence there might only be seasonally- and/or depth-related, in association with monsoonal periodicity and the induced Somali Upwelling.

The proposed 33.35 and 35.50 psu values at 15°C, derived from the point data distributions, have been indicated on the T-S plots of water masses in the various ocean basins (Fig. 29). Bearing in mind the night depth range (100-200 m) for both species, it can be seen that: (1) in the Atlantic Ocean, these distributional parameter values are transgressed by both North Atlantic Central Water and South Atlantic

Central Water masses (more saline, higher temperature); and (2) in the Indian Ocean, they are transgressed by Indian Central Water only. That is, the distribution of *B. indicus* appears to be related hydro-chemically to North and South Atlantic Central Water and to South Indian Central Water. It must also be noted that the T-S characteristics of Indian Equatorial Water fall below the above-mentioned distributional cut-off values. In the Pacific Ocean, the T-S characteristics of east North Pacific Central Water, Pacific Equatorial Water, and east South Pacific Central Water all fall below the proposed boundary values. That is, the distribution of *B. longipes* is related to Indian and Pacific Equatorial Waters masses, and to east North Pacific Central and South Pacific Central Water masses. It should be noted that the proposed parameters for *B. indicus* are met by Western South Pacific Central Water (Figs. 28-29). However as pointed out above, it appears that this region might be zoogeographically isolated from the south-east Indian Ocean populations of this species.

In summary, it appears that the distributions of *B. indicus* and *B. longipes* are related to the particular T-S characteristics of the various Central Water masses of the world's oceans, with the obvious extrapolation that there is indeed niche separation between these two species, despite the fact that their behavioural verticality patterns are similar.

Remarks

According to Nafpaktitis and Nafpaktitis (1969), both *B. longipes* (1 specimen: 12.5 mm SL) and *B. indicus* (2 specimens: 12-13 mm SL) were taken at 17°58'S, 65°34'E (Anton Bruun VI Station 7292), together with *B. photothorax* (32 specimens: 16-42 mm SL). Collection data exist for

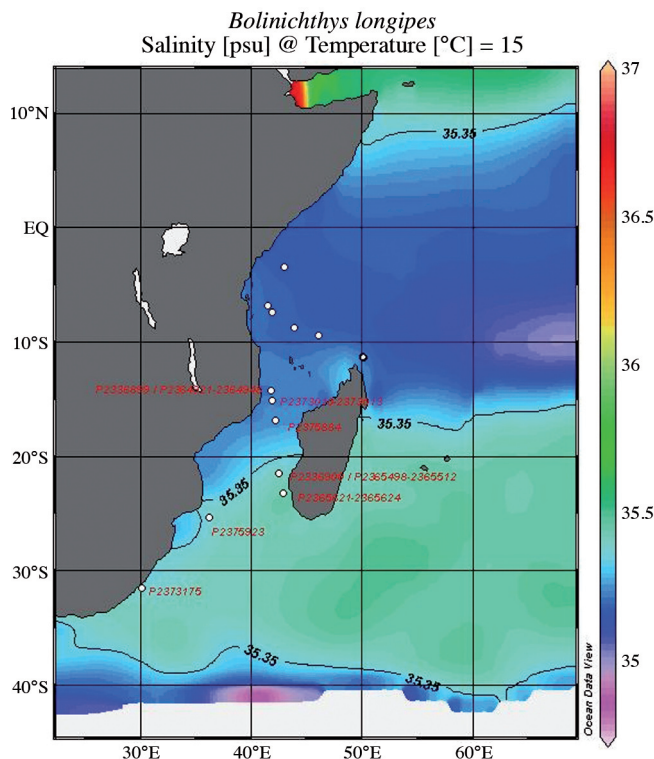


Figure 30. - *Bolinichthys longipes*. Geographic distribution in relation to salinity at 15°C in SW Indian Ocean (ZMUC data).

B. indicus (LACM 31381-6: 2 specimens) and *B. photothorax* (LACM 31316-4: 32 specimens) from this station, but there is no matching specimen in the LACM collection (or elsewhere) for the supposed single *B. longipes* specimen also reported from this station. The occurrence of *B. longipes* at this station is therefore regarded with reservation, and has not been included in the geographic data sets.

SIO collection specimens of *B. longipes* reported from the Atlantic (SIO 63-540: 32°26.7'S, 008°49.0'E) and Indian Oceans (SIO 69-26: 23°20.4'S, 050°34.7'E; SIO 69-22: 20°47.9'S, 058°11.17'E; SIO 69-25: 28°02.3'S, 066°03.6'E; SIO 61-37: 33°27.7'S, 072°32.7'E) should be treated with reservation. As these records fall within the proposed distributional range of *B. indicus*, they have not been included in the distribution of *B. longipes*.

ZMUC specimens from the Mozambique Channel and further south in the Agulhas Current generally correlate with the T-S characteristics of pockets of North Indian Equatorial Water, extending southwards to 31°33'S, 036°13'E (P2373164-2373175) off the east coast of South Africa (Fig. 30). The species was also taken at two stations (*Dana* St. 3957: 395823°11'S, 42°54'E; *Dana* St. 3958: 21°30'S, 42°32'E) off the west coast of Madagascar (Fig. 30). Due to the porosity of the hydro-chemical front in the region of the Mascarene Plateau (New *et al.*, 2005), it may be expected that *B. longipes* will also be found sporadically off the east

coast of Madagascar.

***BOLINICHTHYS NIKOLAYI* BECKER, 1978**

(Figs 31-39, Tabs I-IV)

Synonymy

Bolinichthys nikolayi Becker, 1978: 259-264, figs. 1-2 (4) (19°39'S, 175°10'W). Holotype: ZIN 43780; paratype: IORAS (1 spec. 32.5 mm TL: data as in holotype).

Bolinichthys nikolayi: Paxton, 1979: 7; Brandt, 1981: tab. 2; 1983: tab. 2; Becker, 1983: 213, figs. 49 (b), 50 (6); Paxton *et al.*, 1989: 255; Paxton and Hulley, 1999: 1962; Hoese *et al.*, 2006: 511; Eschmeyer, 2008.

Bolinichthys nikolavi: Griffiths and Wadley, 1986: tab. 2.

Bolinichthys nikolai: Rivaton and Bourret, 1999: 238, pl. 110 (10-11).

Meristics

D 13 (10-12); A 14 (10-13); P 11 (9-10); AO 6 (4-7) + 3 (2-4), total 9 (6-10); GR 4 (3) + 1 + 8 (6-10), total 13 (11-14).

Description

Eye large, aphakic space present; crescent of white tissue on posterior half of iris. Large, re-curved, preopercular spine absent. Posterodorsal margin of operculum anteriorly concave, distance between posterior cusps about equal to length of base of pectoral fin in small specimens (Fig. 32), much longer than pectoral base in larger specimens (Fig. 31); subopercle serrate; interopercle smooth. Origin of dorsal fin about on vertical through outer base of pelvic fin; origin of anal fin behind vertical through posterior end of base of dorsal fin; pectoral fins long, probably reaching to SAO₃; pelvic fins reaching to anus; adipose origin in advance of end of base of anal fin.

Vn at anterior border of eye, between nasal rosette and anterior edge of pupil. Small post-ocular photophores absent. Op₁ below level of posterior angle of mouth, just above ventral margin of posterior flange of preopercle; Op₂ larger, above level of ventral margin of orbit. PLO above or in con-

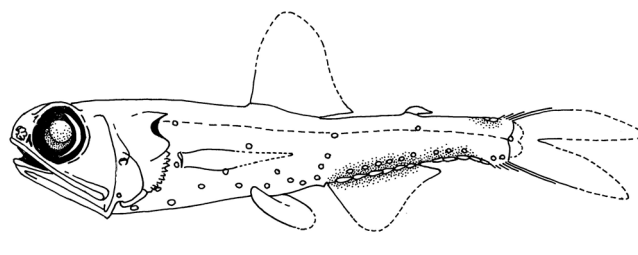


Figure 31. - *Bolinichthys nikolayi*. Lateral view (MNHN 1991-124: SL 35.0 mm). Scale = 10 mm.

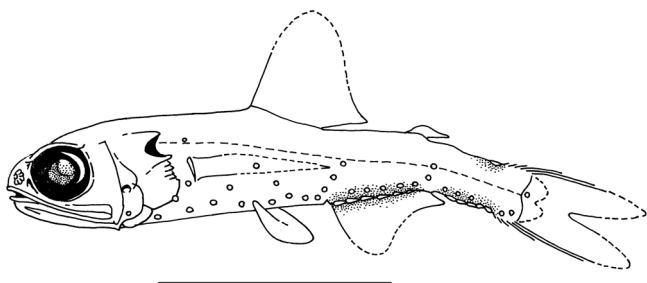


Figure 32. - *Bolinichthys nikolayi*. Lateral view (AM I 19760008: SL 22.7 mm). Scale = 10 mm.

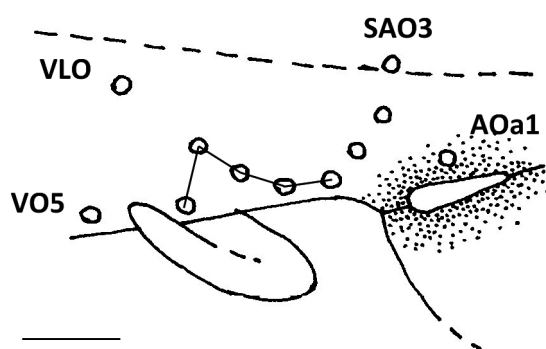


Figure 33. - *Bolinichthys nikolayi*. Left lateral view of torso showing VO and SAO photophore orientation (AM I 19761009: SL 18.1 mm). Scale = 1 mm.

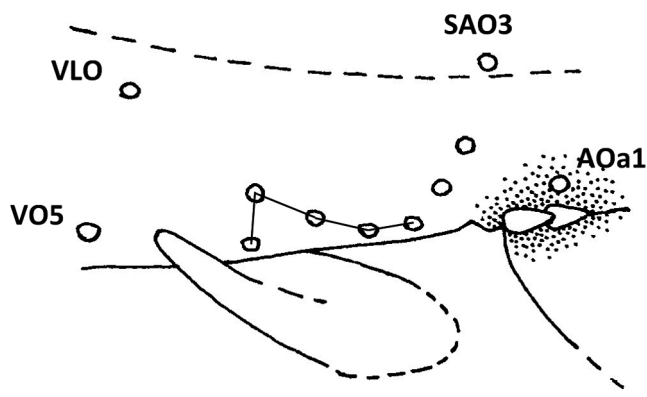


Figure 34. - *Bolinichthys nikolayi*. Left lateral view of torso showing VO and SAO photophore orientation (MNHN 1991-124: SL 35.0 mm). Scale = 1 mm.

tact with lateral line. PVO₁ in advance of PVO₂, which is in front of ventral base of pectoral fin. 5 PO; with PO₃ raised above line through centres of PO₁-PO₂; with PO₄ dorsal to level of PVO₁, and nearer to PO₅ than PO₃; and with PO₅ in front of outer pelvic base. VLO 2-3 photophore diameters below lateral line, slightly anterior, on or slightly posterior to vertical through outer pelvic base. 5 VO; with VO₂ highly and abruptly elevated, at or slightly above line connecting VO₃-VO₅; VO₂-VO₅ distinctly angulate, with VO₂-VO₄ in

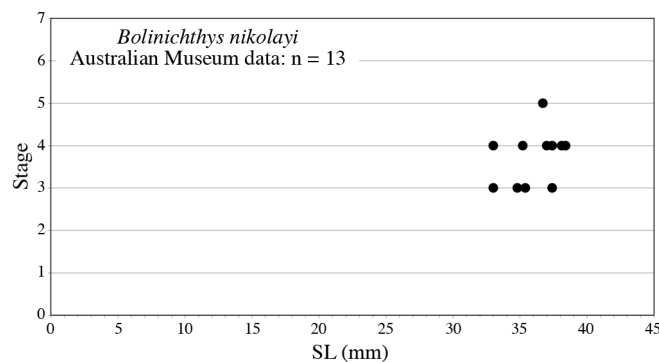


Figure 35. - *Bolinichthys nikolayi*. Relationship of sexual maturity to standard length (SL).

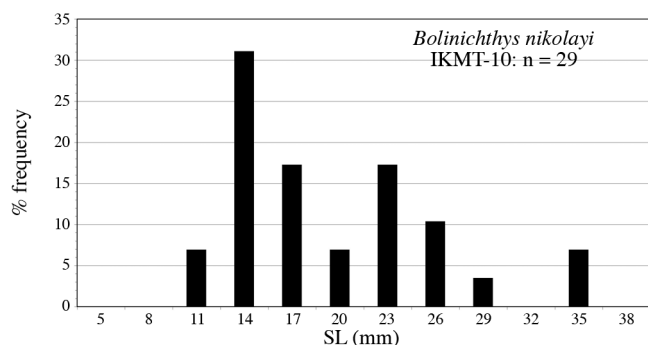
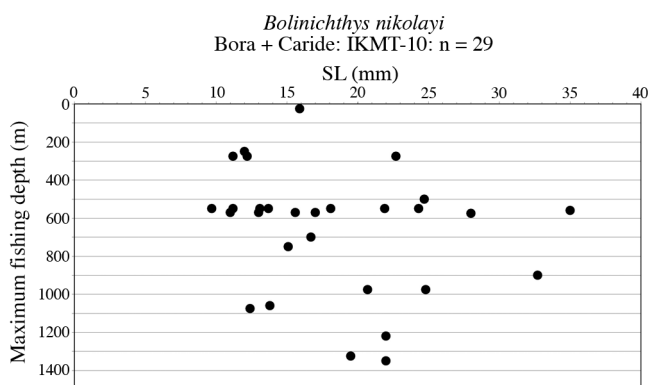
a straight descending line, occasionally with VO_3 displaced (Figs. 32-34). SAO_1 posterior to vertical through VO_5 , at about level of PO_4 ; with SAO_2 on or slightly in front of vertical through origin of anal fin, usually closer to SAO_1 than SAO_3 ; and with SAO_3 at or just above lateral line, on or posterior to vertical through origin of anal fin. AO series divided into AOa and AOp, with AOa₁ and last AOa level; AOp evenly spaced and all posterior to end of anal fin. 2 Pol (by definition), with Pol₁ slightly raised or elevated above AOa series, about on vertical through middle of adipose fin or slightly posterior; and with Pol₂ at or just above lateral line, well behind vertical through base of adipose fin. 2+1 Prc; with Prc₂ about 1 photophore diameter posterodorsal to Prc₁; and with Prc₃ well behind Prc₂ and above level of lateral line. Supracaudal luminous organ consisting of 1-2 luminous, scale-like patches; infracaudal organ consisting of 4-6 luminous, scale-like patches, extending anteriorly from procurrent caudal rays to, or slightly anterior to, vertical through AOp₁. Luminous tissue on top of head and on sides of body absent. Scale-like patch of luminous tissue at base of pelvic fin absent. No luminous patches along base of dorsal fin; 6-7 elongate, luminous scale-like patches along base of anal fin, commencing about at origin of anal fin, with second patch at AOa₁, and extending posteriorly to about last AOa (Figs. 33, 34).

Size and maturation

Maximum recorded size 41 mm SL; females sexually mature from about 33 mm SL (Fig. 35); large females have been taken in July, and gravid female specimens (Stages IV) have been captured in December (Dr. John Paxton, pers. comm.). This suggests that spawning takes place from mid- to late summer. Limited length-frequency data suggest that *B. nikolayi* may have a two-year life cycle (Fig. 36).

Depth distribution

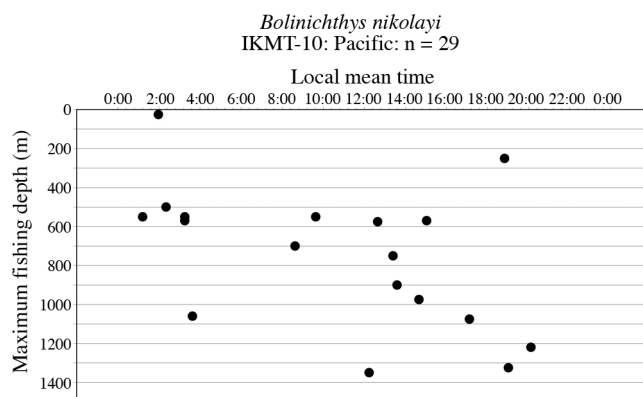
Bolinichthys nikolayi has been taken in nets fished to 1760 m, with the shallowest depth of capture being 25 m.

Figure 36. - *Bolinichthys nikolayi*. Length-frequency histogram.Figure 37. - *Bolinichthys nikolayi*. Variation of standard length (SL) with maximum fishing depth.

Limited catch data (GBIF: <http://www.gbif.org>) suggest that the species is fished most frequently (28%) in trawls to 550–650 m; specimens larger than about 25 mm appear to occur at, and below these depths (Fig. 37). In the tropical Central Pacific, the species is absent from the upper 500 m during the day (Figs. 2, 38); and apparently only small specimens (< 25 mm SL) migrate into the upper 300 m at night (Figs. 37–38). However, further sampling is required to confirm these observations.

Geographic distribution

Bolinichthys nikolayi is an oceanic, mesopelagic species, confined to the western South Pacific Ocean (see Remarks below) between about 10° and 39°S, and is known from the continental slope of the Australian East Coast to 140°W (Fig. 39). The restricted geographic distribution in the Pacific suggests a relationship to the more saline, but better oxygenated, Western South Pacific Central Water mass (WSPCW) (Emery, 2001: fig. 3), and can generally be circumscribed by the 35.35 psu isohaline and 3.6 ml.litre⁻¹ dissolved oxygen isopleth at 200 m (Fig. 39). There is one record in the Coral Sea (MCZ 167367: 13°34'S, 148°04'E: 13 mm SL) and several records off south-east Victoria, at the south-

Figure 38. - *Bolinichthys nikolayi*. Diel migration pattern.

ern end of the East Australian Current eddy system, which slightly transgress the proposed limits. The relationship to more saline waters is supported by the fact that catch records (including those of the most mature specimens known) appear to be more frequent in the Tasman Sea area off the south-east slope of Australia than elsewhere. Here WSPCW is significantly more saline than elsewhere, due to the Bass Strait Water Cascade phenomenon (Tomczak and Godfrey, 2002). In the western South Pacific, where oxygen concentrations at 200 m are < 3.6 ml.litre⁻¹, *B. nikolayi* is replaced by its close congener *B. pyrsobolus* (see below). It is interesting to note that similar distributional parameters are given by Haffner (1952) for the distribution of *Chauliodus sloani dannevigii*, namely occupation of the Western South Pacific Central Water mass with oxygen saturation levels between 3–4 ml.litre⁻¹.

Remarks

There are two erroneous records of *B. nikolayi* from outside the western South Pacific Ocean. Re-examination of the single, badly-rubbed specimen (IORAS 00857: 15°21'S, 42°12'E) from the northern Mozambique Channel confirms that it should be referred to *Taaningichthys bathyphilus*: the length of the anal fin base is much shorter than the caudal peduncle length; traces of luminous tissue indicate that the supracaudal and infracaudal luminous tissue extends more than 50% of the caudal peduncle length; Pol₂ is well posterior to the vertical through posterior base of the adipose fin; and there are no traces of luminous tissue along the base of the anal fin. Re-examination of two specimens from off Western Australia (AMS I 31149001: 21°51'S, 113°48'E: 87–89 mm SL) indicates that they should be referred to *Bolinichthys pyrsobolus*: in both, there are 4 VO; the distance PVO₁–PVO₂ is less than distance Op₁–Op₂; the infracaudal luminous scales reach to AOp₂; and there are 3–4 luminous patches along the anal base, and no patches along the dorsal base.

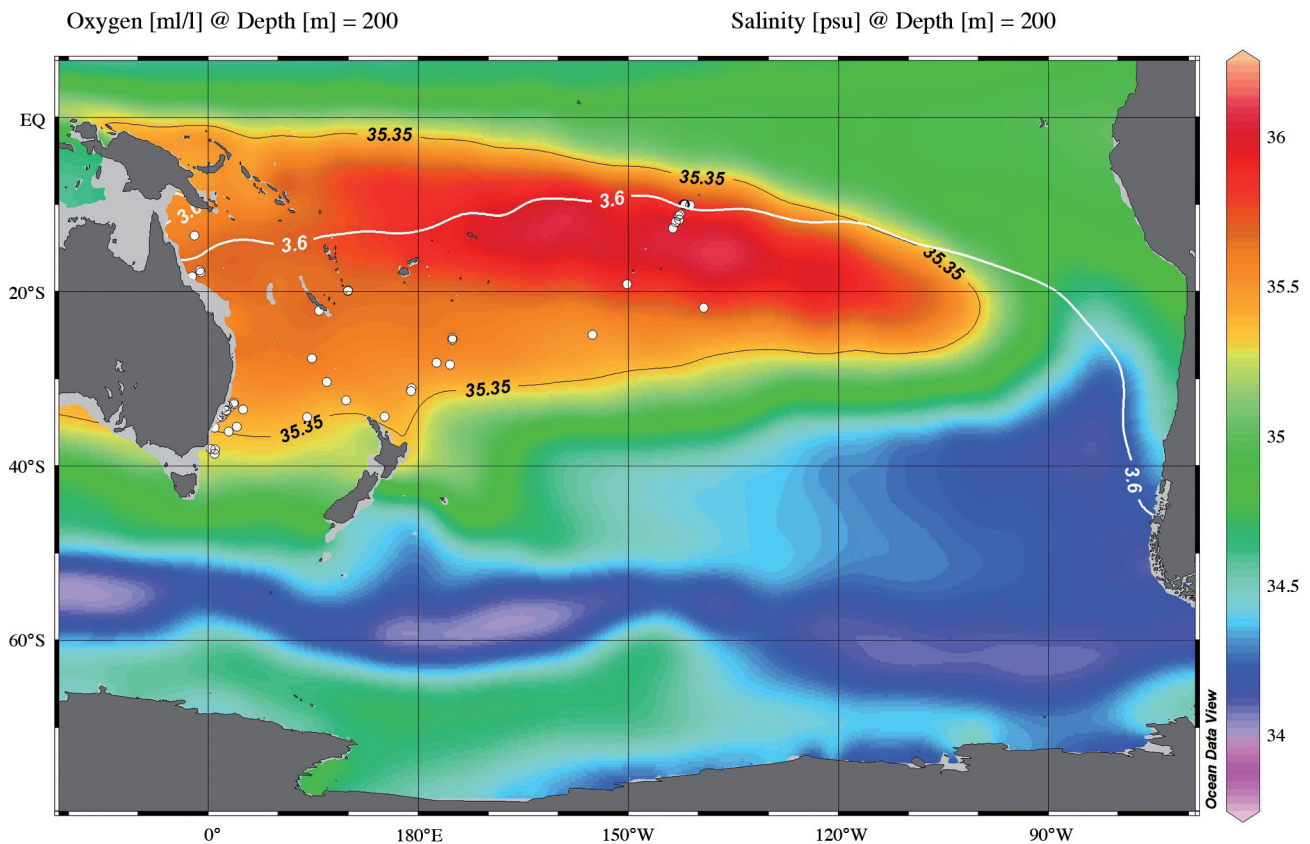


Figure 39. - *Bolinichthys nikolayi*. Geographic distribution in relation to salinity and dissolved oxygen at 200 m. Dissolved $O_2 = 3.6$ ml. litre $^{-1}$; isohaline = 35.5 psu.

***BOLINICHTHYS PHOTOTHORAX* (PARR, 1928)**

(Figs 40-48, Tabs I-IV)

Synonymy

Lampanyctus photothorax Parr, 1928: 81, 95-98, fig. 13 (23°55'N, 77°09'W, 4 000- 7 000 ft w.o.). Holotype: BOC 2263; 53 paratypes: BOC 2262 (7 spec.), 2264 (9 spec.), 2265 (2 spec.), 2266 (6 spec.), 2267 (9 spec.), 2268 (3 spec.), 2269 (1 spec.), 2270 (11 spec.), 2271 (5 spec.).

? *Lampanyctus stilbius* Gilbert, 1908: 235 (near Nukuhiva Island, Marquesas Group, 0-300 fm). Holotype: USNM 757768.

? *Lampanyctus stilbius*: Parr, 1928: 95, fig. 13; 1929: 23; Fowler, 1928: 69.

Lampanyctus photothorax: Norman, 1930: 329 (*partim*); Parr, 1934: 55-56, 59; Bebbe, 1937: 204; Grey, 1955: 289; Eschmeyer, 2008.

Macrostoma photothorax: Fowler, 1936: 1229, fig. 526.

Lampanyctus stilbius: Bolin, 1946: 149; Eschmeyer, 2008.

Lampanyctus (Lepidophanes) pyrsobolus (non Alcock, 1890): Fraser-Brunner, 1949: 1092, fig. (*partim*).

Lepidophanes pyrsobolus (non Alcock, 1890): Bolin, 1959: 35 (*partim*); Briggs, 1960: 175 (*partim*); Becker, 1967b: 119 (*partim*).

Lepidophanes photothorax: Nafpaktitis and Nafpaktitis, 1969:

59-61, Figs. 72-73; Gibbs *et al.*, 1971: 117, 135; Legand *et al.*, 1972: 305, 317-318.

Bolinichthys photothorax: Paxton, 1972: 47; 1979: 6; Parin *et al.*, 1974: 107; 1990a: 202; 1990b: 45; Johnson, 1975: 53, 55; Hartmann and Clarke, 1975: 637, tab. 4; Wisner, 1976: 202-203, tabs. 40-41; Figs. 189-190, 192; Nafpaktitis *et al.*, 1977: 236-238, Figs. 165-166; Backus *et al.*, 1977: 267, 274-275, 277; Nafpaktitis, 1978a: 6; Hulley, 1981: 230, figs. 105a, 106; 1986b: 241, tab. 7; 1990: 401-402; Hopkins *et al.*, 1981: tab III; 1997: tabs. 1, 6; Becker, 1983: 215, figs. 50 (b); 99 (2); Brandt, 1983: tab. 2; Barnett, 1983: tab. 2; 1984: 207, tab. 7; Hopkins and Lancraft, 1984: 155; Becker and Evseenko, 1987: 16 Karnella, 1987: 61; Gartner *et al.*, 1987: 88, tabs. 3, 6; 1989: tab. 1; Paxton *et al.*, 1989: 255; Stickney and Torres, 1989: tabs. 1-2; Brooks and Saenger, 1991: tab. 2; Hopkins and Gartner, 1992: tab. 1; Dalpadado and Gjøsæter, 1993: Appendix 3; Paxton *et al.*, 1995: 1320, fig. 26; Tsarin, 1996: tab. 1; Paxton and Hulley, 1999: 1962; Rivaton and Bourret, 1999: 238, pl. 110 (12-20); Moser and Watson, 2001: tabs. 1-3; Craddock and Hartel, 2002: 950; Moore *et al.*, 2003: 198; 2004: 247, tab. 2; Mundy, 2005: 212; Bonecker and Castro, 2006: 136, tab. 2, 2 figs.; Hoese *et al.*, 2006: 511; Herring, 2007: tab. 4; Eschmeyer, 2008; Hulley and Paxton, in press.

Bolinichthys stilbius: Paxton, 1979: 5.

Remarks on synonyms

The taxonomic status of *Lampanyctus stilbius* Gilbert, 1908 is unclear. Paxton (1979) and Eschmeyer (2008) have suggested that it is questionably a synonym of *B. photothorax*. Although Gilbert (1908) pointed out that the type is in poor condition, the following diagnostic characters indicate that it belongs to the *indicus-longipes-photothorax* subgroup: post-ocular photophores present; VLO at lateral line; and (?) luminous scale at pelvic fin base. Unfortunately the specimen is small (20 mm) and the preopercular region damaged. The GR 4 + 1 + 13 in the type (Dr. Bruce B. Collette, pers. comm.) has a GR₁ count typical of *B. photothorax*, but the GR_u value is more typical of *B. longipes* (Tab. IV). It is therefore impossible to reconcile the type with certainty, and the species must remain a *species inquirenda*.

However, *Lampanyctus stilbius* Gilbert, 1908 described by Bolin (1946) can be referred to *B. photothorax* because post-ocular photophores are present, and there is luminous tissue at the pectoral base and at PVO₁.

Bolin's (1959) GR count of 6 + 1 + 13 confirms that *B. photothorax* is one of the species incorporated in his synonymy of *B. pyrsobolus*.

Meristics

D 13 (12-14); A 14 (13-15); P 14 (12-13); AO 7 (5-8) + 4 (3-6), total 11 (9-12); GR 6 (5-7) + 1 + 13-14 (11-16), total 20-21 (18-23).

Description

Eye large, aphakic space present; crescent of white tissue on posterior half of iris. Large, anteriorly re-curved spine present on ventral margin of preopercle. Posterodorsal margin of operculum anteriorly concave, distance between cusps about equal to length of base of pectoral fin; ventral margins of subopercle and interopercle smooth. Origin of dorsal fin about on, or slightly behind vertical through outer base of pelvic fin; origin of anal fin behind vertical through posterior end of base of dorsal fin; pectoral fins very long, reaching to adipose fin origin or beyond; pelvic fins reaching to anus; adipose origin in advance of end of base of anal fin.

Vn at anterior border of eye, between nasal rosette and anterior edge of pupil. Three small post-ocular photophores. Op₁ below level of posterior angle of mouth, just above ventral margin of posterior flange of preopercle; Op₂ larger, just below level of ventral margin of orbit. PLO at, immediately above or just below lateral line. PVO₁ directly below, or slightly in advance of PVO₂, which is in front of middle of base of pectoral fin. 5 PO; with PO₃ raised above line through centres of PO₁-PO₂; with PO₄ dorsal to level of PVO₁, and nearer to PO₅ than PO₃; and with PO₅ in front of outer pelvic base. VLO at, or not more than 1 photophore diameter below lateral line, posterior to vertical through outer pelvic base. 5 VO; with VO₂ highly and abruptly elevated, at or slightly

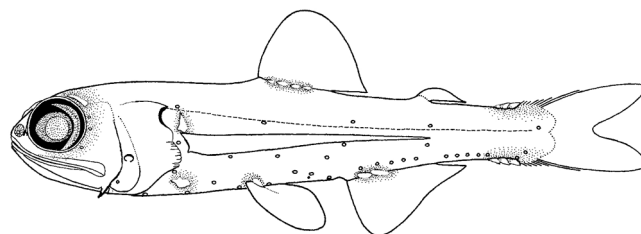


Figure 40. - *Bolinichthys photothorax*. Lateral view (SL 58 mm: after Nafpaktitis *et al.*, 1977).

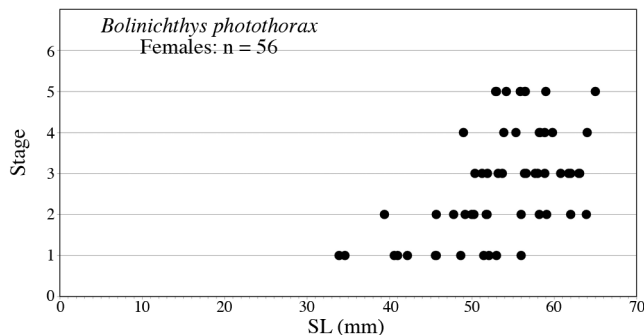


Figure 41. - *Bolinichthys photothorax*. Lateral view (SL 58 mm: after Nafpaktitis *et al.*, 1977).

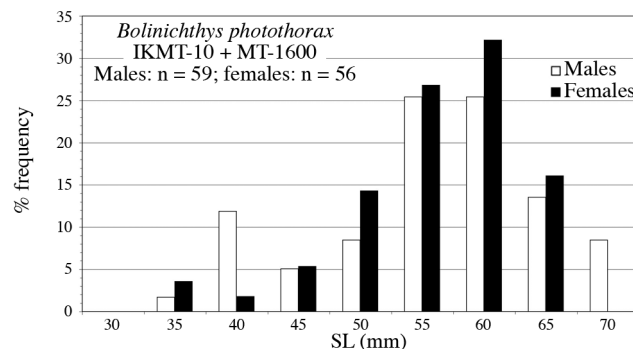


Figure 42. - *Bolinichthys photothorax*. Length-frequency histograms for males and females.

ly above line connecting PO₄-SAO₁; and with VO₃-VO₅ in straight descending line. SAO₁ slightly anterior to, on or posterior to vertical through VO₅, at about level of PO₄; with SAO₂ in front of vertical through origin of anal fin, closer to SAO₁ than SAO₃; and with SAO₃ just above lateral line, posterior to vertical through origin of anal fin. AO series divided into AOa and AOp, with AOa₁ slightly depressed and last AOa somewhat raised; AOp evenly spaced and all posterior to end of anal fin. 2 Pol (by definition), with Pol₁ elevated above AOa series, on or slightly posterior to vertical through middle of adipose fin; and with Pol₂ at or just above lateral line, on or behind vertical through base of adipose fin. 2+1 Prc; with Prc₂ about 1-2 photophore diameters posterodorsad to Prc₁; and with Prc₃ well behind Prc₂ and above level of lateral line.

Minute secondary photophores on trunk. Supracaudal luminous tissue consisting of 3 scale-like patches; infracaudal luminous tissue with 2-3 (sometimes 4) scale-like patches, extending anteriorly from procurent caudal rays to level of last AOp. 2-4 pairs (sometimes coalesced) of patches of luminous tissue on top of head, posterior pair being largest, and each patch often associated with small, black-backed secondary photophores; patches apparently sexually dimorphic, being denser and more developed and circumscribed in males than in females. Irregularly-shaped patch of luminous tissue between upper base of pectoral fin and PLO present; luminous patch posterior and ventral to PVO₁ present; single, scale-like patch of luminous tissue at base of pelvic fin. 2-4 luminous patches along base of dorsal fin; 2-4 elongate, luminous patches at base of anal fin, each under an AOa photophore and starting at level of AOa₁.

A small specimen (ISH 1100-1974: WH 61-II/1974: 02°27'N, 34°52'W, 350m; SL 36 mm) with a trace of luminous tissue above the upper P base only on left side; no luminous tissue posteroventral to PVO₁ (both sides); preopercle with spine; and GRu = 6, AOa = 6 (both sides).

Size and maturation

Maximum size to 73 mm SL; females sexually mature from about 49 mm SL (Fig. 41); sexual dimorphism not obvious (Fig. 42). Late winter / spring spawner at Bermuda (Karnella, 1987); summer / autumn spawner near Hawaii (Clarke, 1973). Gravid females have been taken in the SW Atlantic in February and May.

Depth distribution

The size range of specimens of *Bolinichthys photothorax* sampled by small, scientific trawls (e.g., 10' IKMT) is smaller than that sampled by larger, commercial nets (e.g., Engels MT-1600) (Fig. 43). Pooled depth distribution data for the Central Atlantic (ISH data: Engels MT-1600) and Central Pacific (MNHN data: 10' IKMT) indicate that the least depth of capture for the species during the day (06:00-17:00) was 275 m; at night (19:00-04:00) was 50 m. In the Atlantic at least, there appears to be no variation in specimen size with latitude; large specimens were taken throughout the geographic distributional range (Fig. 44).

The diel migration pattern for *B. photothorax* in the equatorial Central and Western Pacific is given in figure 45. These data should be viewed against the sampling intensity at various depths/times during the series of *Bora* and *Caride* cruises (Fig. 2). During the day (06:00-19:00), the species occurs generally below about 500 m, while at night (19:00-04:00) it migrates into the upper 90-150 m (Fig. 45). The rate of migration appears to be relatively rapid (approximately 200 m in an hour). Unfortunately during these cruises, sampling during the morning and evening crepuscular periods (04:00-06:00 and 17:00-19:00 respectively) was less intensive than

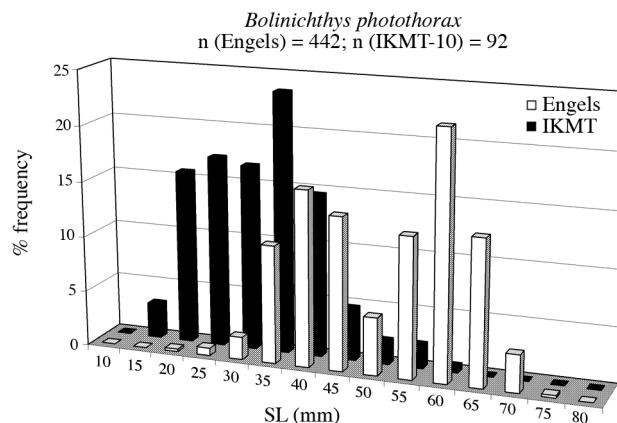


Figure 43. - *Bolinichthys photothorax*. Length-frequency histograms for specimens from IKMT-10 and MT-1600 haul.

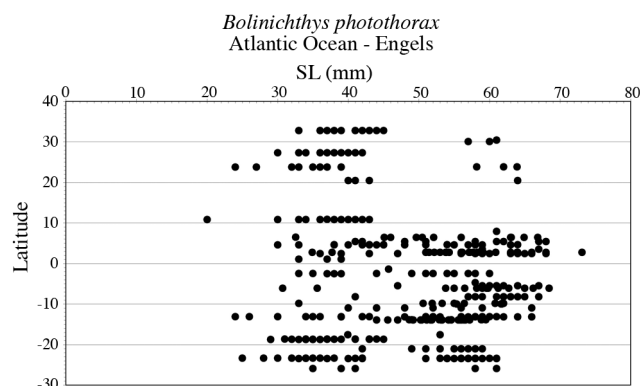


Figure 44. - *Bolinichthys photothorax*. Variation of standard length (SL) with latitude.

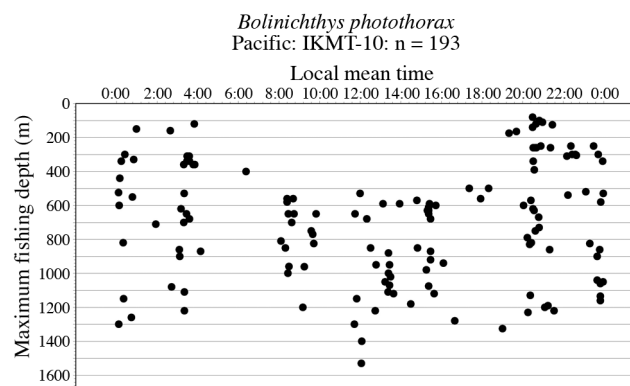


Figure 45. - *Bolinichthys photothorax*. Diel migration pattern.

either during the day or at night (Fig. 2).

The depth of capture with regard to day (06:00-17:00) and night (19:00-04:00) periods is given in figures 46-47. At night, both small specimens (< 40 mm SL) and larger specimens (> 40 mm SL) were taken in trawls fished to 110 m and deeper. During the day, specimens larger than 40 mm SL were only taken in nets fished deeper than about 550 m.

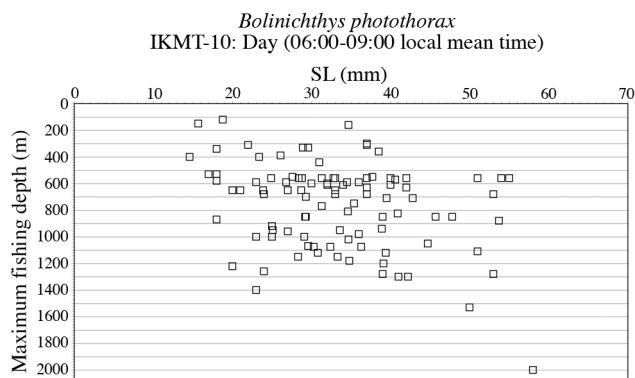


Figure 46. - *Bolinichthys photothorax*. Variation of standard length (SL) with maximum fishing depth of day haul.

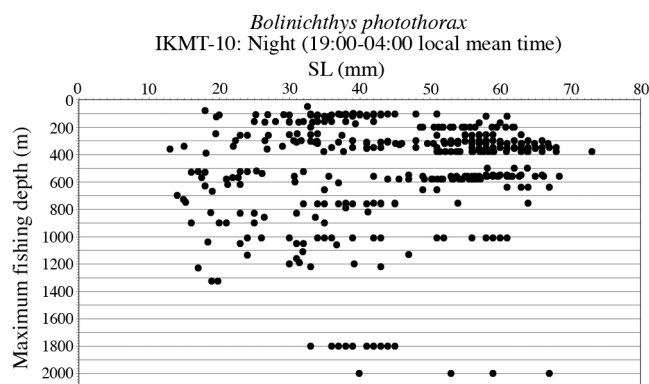


Figure 47. - *Bolinichthys photothorax*. Variation of standard length (SL) with maximum fishing depth of night haul.

However, smaller specimens (< 40 mm SL) were often captured below about 300m during the day, and were infrequently taken in the upper 150 m (Fig. 46). To summarize, the entire population appears to undertake comparatively rapid, diel migration, with smaller specimens migrating from shallower day living depths than larger specimens.

More locally, the literature indicates the following depth distributions: Western North Atlantic (Brazil to south of the Grand Banks) - in depths of 425-750 m by day and 40-500 m at night (with peak abundance at 75 m) (Moore *et al.*, 2003); Central and South Atlantic - least depth of capture 560 m for larger specimens (> 44 mm SL) (Hulley, 1981); Central North Pacific (near Hawaii) - in depths of 95-225 (night) and 490-690 m (day); adult specimens (> 53 mm SL) not taken above day living-depth; at night, small specimens (< 20 mm SL) in upper 100-200m, with no specimens > 30 mm SL in upper 200 m (Clarke, 1973); Western North Pacific (off Japan) - least depth of capture 830 m; Western South Pacific: generally below 600 m, with smaller specimens (< 30 mm SL) in upper 230 m; Central and Equatorial Pacific - least depth of capture 540 m, but with small specimens (< 14 mm SL) in upper 100-330 m.

Geographic distribution

Bolinichthys photothorax has an oceanic, mesopelagic, Broadly Tropical Pattern (Holo-eurytropical Subpattern) (Hulley, 1981). It is distributed in Gulf of Mexico, Caribbean and western Atlantic (45°N-25°S), with isolates to 38°S; in the eastern Atlantic between 33°N-35°S, but is absent in Mauritanian and Benguela upwelling regions. It is

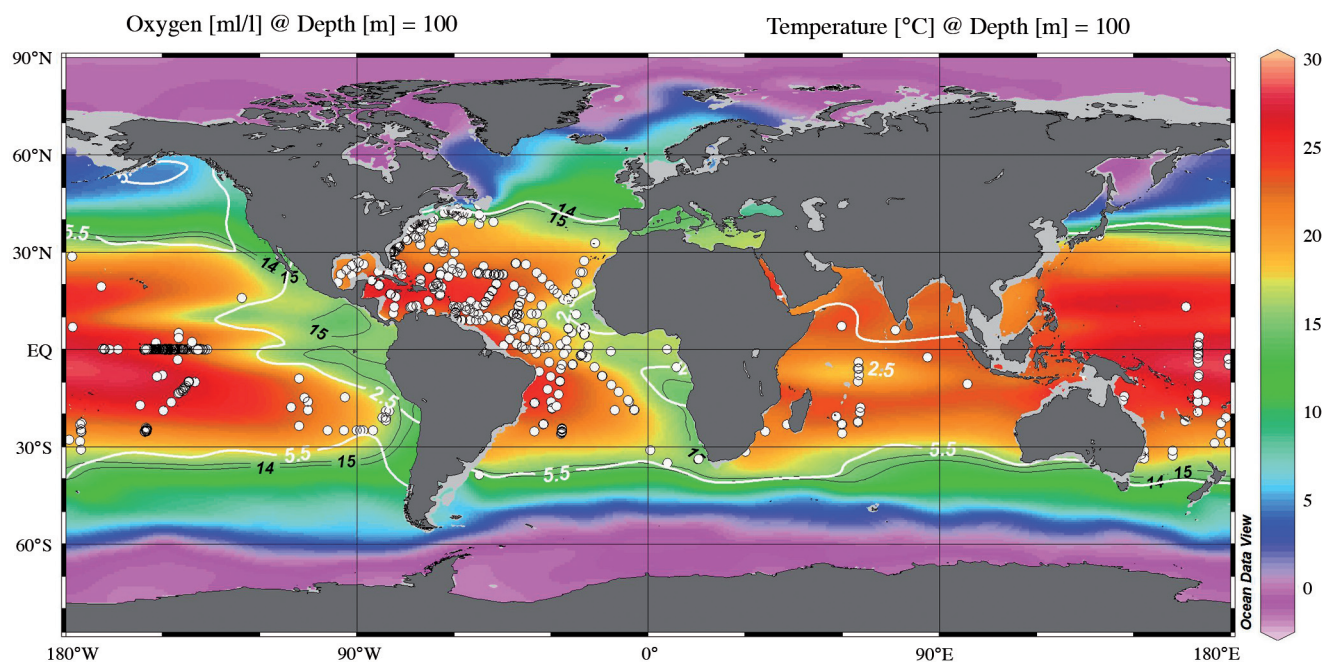


Figure 48. - *Bolinichthys photothorax*. Geographic distribution in relation to temperature and dissolved O₂ at 100 m.

found in the central Indian Ocean (08°N-26°S), but has not been recorded from eastern South Indian Ocean near Australia. It occurs in the western Pacific (east of 180°) between 12°N-29°S, with one specimen (CHIB ZF-04263a: IKMT-10; 961 m) taken at 35.03°N, 139.35°E within the Kuroshio Current system; and extends southwards to 33°S in East Australian Current eddy system. In the central Pacific it is found between 29°N-25°S; and in the eastern Pacific from 16°N-24°S. Its geographic distribution appears to be circumscribed by 14-15°C isotherms and the 2.5-5.5 ml.litre⁻¹ dissolved O₂ isopleths at 100 m (Fig. 48).

***BOLINICHTHYS PYRSOBOLUS* (ALCOCK, 1890)**

(Figs 49-55, Tabs I-IV)

Synonymy

Scopelus pyrsobolus Alcock, 1890: 218 (15°38'N, 82°30'N). Holotype: ZSI F.12839, Menon and Yazdani, 1968).

Scopelus pyrsobolus: Misra, 1949: 37, fig. 1; Eschmeyer, 2008.

Myctophum pyrsobolum: Garman, 1899: 401.

Serpa blacki Fowler, 1934: 284-285, fig. 44 (Cape Overton Lighthouse, Iligan Bay, Mindinao, Philippines). Holotype: USNM 92312; paratypes USNM 122359 (2 spec.) ANSP (1 spec., missing).

Serpa blacki: Paxton, 1979: 5, 6; Eschmeyer, 2008.

Lampanyctus (Lepidophanes) pyrsobolus: Fraser-Brunner, 1949: 1092, fig. (partim).

Lampanyctus (Lepidophanes) blacki: Fraser-Brunner, 1949: 1092, fig.

Lampanyctus pyrsobolus: Misra, 1952: 419, text-fig. 30.

Lepidophanes pyrsobolus: Briggs, 1960: 175 (partim); Nafpaktitis and Nafpaktitis, 1969: 57; Parin *et al.*, 1973: 118, fig. 20 (5).

Bolinichthys blacki: Paxton, 1972: 47; Johnson, 1975: 59, figs. 1-4; Becker, 1978: fig. 2 (2).

Bolinichthys pyrsobolus: Paxton, 1979: 5, 6; Becker, 1983: 213, figs. 49 (d), 99 (5); Moser *et al.*, 1984: tab. 61; Paxton *et al.*, 1989: 255; Dalpadado and Gjøsæter, 1993: Appendix 3; Paxton and Hulley, 1999: 1962; 2000: 593; Mundy, 2005: 212; Hoesel *et al.*, 2006: 511; Eschmeyer, 2008.

Bolinichthys nanshanensis: Yang and Huang, 1992: 77-80, tab. 1, fig. 1 (06°20'N, 114°05'E, 0-975 m). Holotype: SCSIO 86(27)-

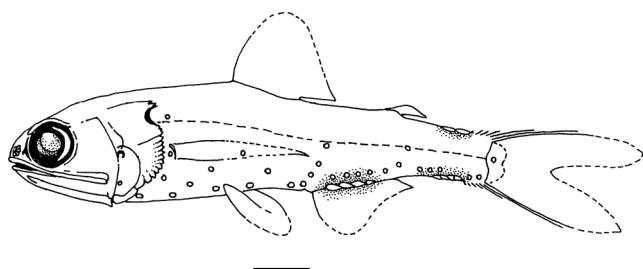


Figure 49. - *Bolinichthys pyrsobolus*. Lateral view (AM I 31149001: 86.4 mm SL). Scale = 10 mm.

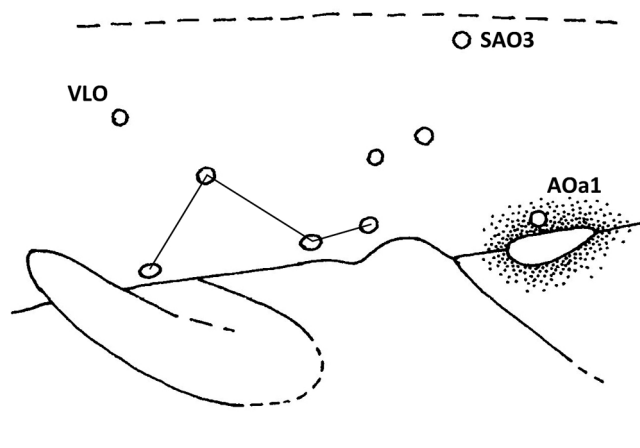


Figure 50. - *Bolinichthys pyrsobolus*. Left lateral view of torso showing VO and SAO photophore orientation (AM I 22816008: 88.7 mm SL). Scale = 10 mm.

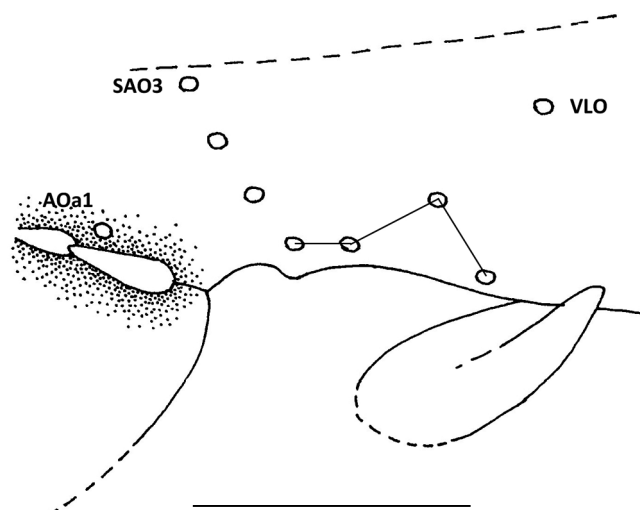


Figure 51. - *Bolinichthys pyrsobolus*. Right lateral view of torso showing VO and SAO photophore orientation (MNHN 1991-4289: 73.1 mm SL). Scale = 10 mm.

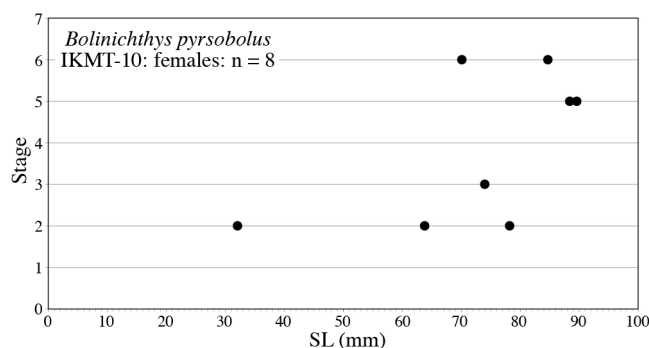


Figure 52. - *Bolinichthys pyrsobolus*. Relationship of sexual maturity to standard length (SL).

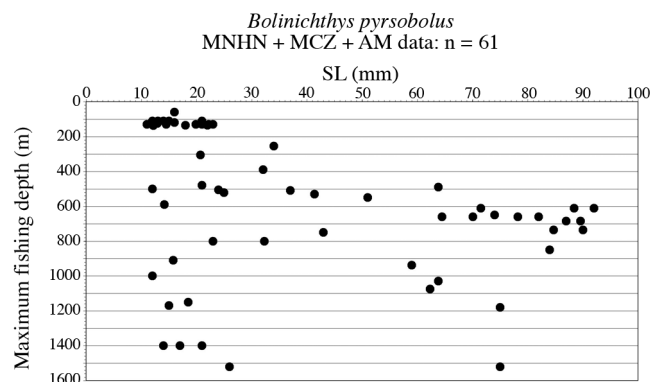


Figure 53. - *Bolinichthys pyrsobolus*. Variation of standard length (SL) with maximum fishing depth of haul.

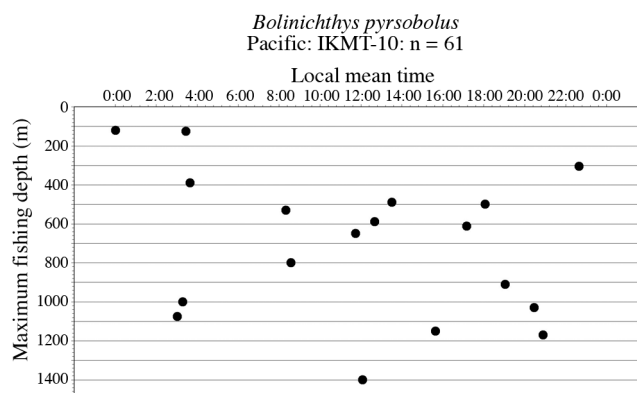


Figure 54. - *Bolinichthys pyrsobolus*. Diel migration pattern.

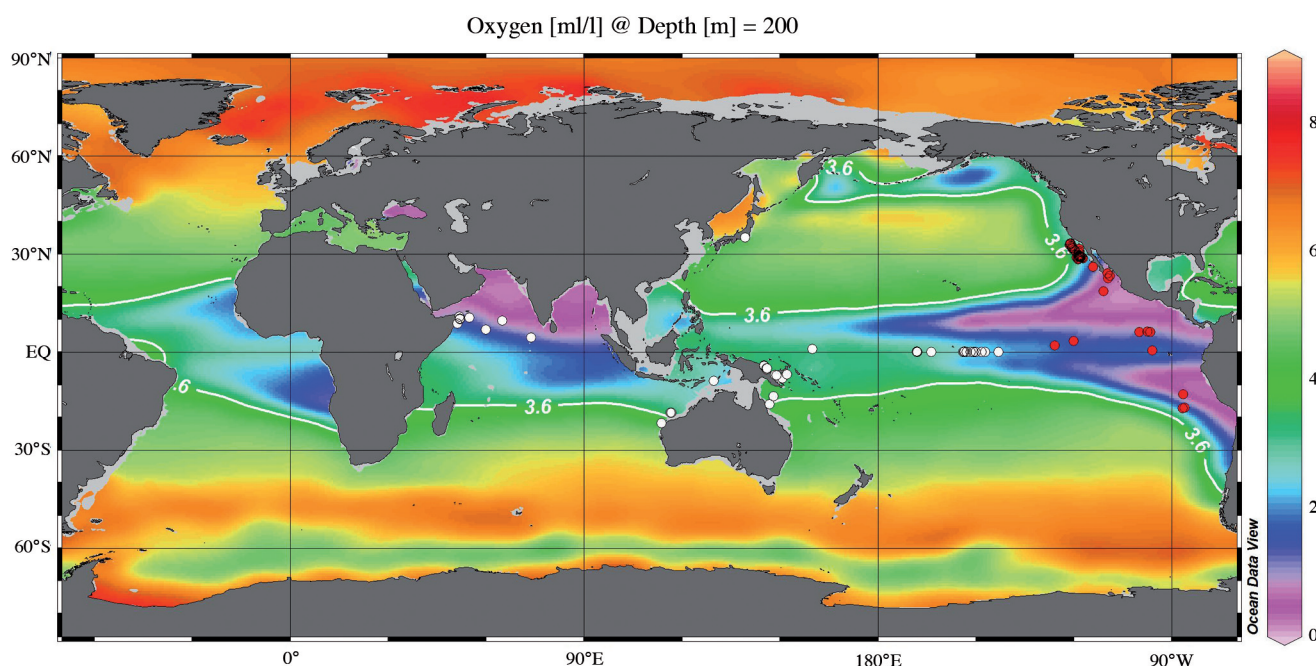


Figure 55. - *Bolinichthys pyrsobolus*. Geographic distribution in relation to oxygen concentration (ml/litre) at 200 m. Red data points = LACM and Parin *et al.* (1973) records.

010; paratype SCSIO 86(27)-011.

? *Bolinichthys nanshanensis*: Paxton and Hulley, 2000: 593.

Bolinichthys nanshanensis: Eschmeyer, 2008.

Remarks on synonyms

The inadequacy of the type description by Alcock (1890), coupled with the lumping of all Atlantic species of the genus under the name *Lepidophanes* (= *Bolinichthys*) *pyrsobolus* by Bolin (1959), has led to considerable confusion in the identity of specimens in museum collections. Misra's (1949: fig. 1) re-description of the type scarcely improved matters, since he figured 3 small post-ocular photophores and the distance $PVO_1-PVO_2 > Op_1-Op_2$, (both diagnostic characters of the *longipes-indicus-photothorax* species group), together

with the absence of a luminous scale at the pelvic base (diagnostics for the *supralateralis-distofax-nikolayi-pyrsobolus* subgroup). Misra (1949: fig. 1; 1952: text-fig. 30) also illustrated only 3 VO photophores, but in the characteristic positions of VO_2-VO_3 . No post-ocular photophores were observed by Paxton (1979: 5) during his re-examination of the type. In addition, his re-examination confirmed that: VLO is only slightly nearer to the lateral line than the outer pelvic base; VO_2 is elevated to the level of the line PO_4-SAO_2 ; 3 luminous patches are along the base of the anal fin; and GR 5 + 1 + 12.

Paxton's (1979) recognition of *B. blacki* as a junior synonym of *B. pyrsobolus* is supported. In *B. blacki* (Fowler, 1934: fig. 44), the post-ocular photophores are absent; the

distance PVO_1 - PVO_2 is subequal to Op_1 - Op_2 ; the luminous patch at the pelvic base is absent; the VLO is well below the lateral line; and the VO_2 is distinctly elevated, so as to form an angulate series. In addition, Johnson (1975) has reported GR 6 + 1 + 13 (12-14) for the type and paratypes.

The recognition of *B. nanshanensis* as a separate species by Yang and Huang (1992: fig. 1) was based mainly on the low VO count (4) and the number of infracaudal luminous patches (5). This latter characteristic is however difficult to interpret, as infracaudal patches in the genus tend to coalesce with increasing size. Yang and Huang (1992) showed that the infracaudal luminous patches extend anteriorly to AOp_2 . Our data indicate that the number of VO photophores can vary between 4 (84%: 27 specimens) and 5 (6%: 2 specimens: AM I22810023, I22813015), and can even vary on the two sides of the same specimen (9%: 3 specimens: AM I22813015, I22816008, MNHN 2000-1980). In most cases, the infracaudal luminous tissue reached anteriorly to AOp_2 , and there are typically 3-5 supra-anal luminous patches. These findings, together with consideration of the geographic distributions of the material, indicate to us that *B. nanshanensis* should be regarded as a junior synonym of *B. pyrsobolus*.

Meristics

D 13 (11-12); A 13 (12-15); P 11-12 (13-15); AO 5 (4-6) + 3 (4), total 8 (7-10); GR 5-6 (4) + 1 + 12 (10-13), total 19 (17-20).

Description

Eye large, aphakic space present; crescent of white tissue on posterior half of iris. Large re-curved preopercular spine absent. Posterodorsal margin of operculum anteriorly concave, distance between cusps about twice length of base of pectoral fin; posterior margin of subopercle serrate; margin of interopercle smooth. Origin of dorsal fin about on or slightly behind vertical through outer base of pelvic fin; origin of anal fin behind vertical through posterior end of base of dorsal fin; pectoral fins long, reaching at least to SAO_3 ; pelvic fins reaching to about anus; adipose origin in advance of end of base of anal fin.

Vn at anterior border of eye, between nasal rosette and anterior edge of pupil. Small post-ocular photophores absent. Op_1 below level of posterior angle of mouth, just above ventral margin of posterior flange of preopercle; Op_2 larger, above level of ventral margin of orbit, sometimes close to midline of orbit (Fig. 49). PLO above or in contact with lateral line. PVO_1 slightly in advance of PVO_2 , which is in front of middle of base of pectoral fin. 5 PO; with PO_3 raised above line through centres of PO_1 - PO_2 ; with PO_4 dorsal to level of PVO_1 , and nearer to PO_5 than PO_3 ; and with PO_5 in front of outer pelvic base. VLO about midway between lateral line and outer pelvic base, or slightly higher, well posterior to vertical through outer pelvic base. 4 (sometimes

5) VO; with VO_2 highly and abruptly elevated; VO_2 to last VO_4 angulate; and with VO_3 - VO_4 in line parallel to ventral contour. SAO_1 posterior to vertical through VO_4 , at about level of PO_4 ; with SAO_2 anterior to, on or posterior to vertical through origin of anal fin, usually closer to SAO_1 than SAO_3 ; and with SAO_3 at lateral line, posterior to vertical through origin of anal fin. AO series divided into AOa and AOp, with AOa₁ and last AOa level; AOp evenly spaced and all posterior to end of anal fin. 2 Pol (by definition), with Pol₁ elevated above AOa series, about on vertical through base of adipose fin; and with Pol₂ at lateral line, well behind vertical through base of adipose fin. 2+1 Prc; with Prc₂ about 1.5-2 photophore diameters posterodorsad to Prc₁; and with Prc₃ well behind Prc₂ and above level of lateral line. Supracaudal luminous tissue consisting of 2-3 scale-like patches; infracaudal luminous tissue consisting of 3-4 scale-like patches, extending anteriorly from procurent caudal rays to in front of level of last AOp. Luminous tissue on top of head and on sides of body absent. Scale-like patch of luminous tissue at base of pelvic fin absent. No luminous patches along base of dorsal fin; 3-5 elongate, luminous patches along base of anal fin, commencing in front of AOa₁ and extending posteriorly to about AOa₄.

Size and maturation

Maximum size to 92 mm SL; females sexually mature from about 70 mm SL (Fig. 52). Mature and expended females (Stages V and VI) have been caught in January and April, suggesting late summer spawning period.

Depth distribution

Available data indicate that there is some size stratification with depth (Fig. 53): small specimens (less than 23 mm SL) have been taken in nets fished as shallow as 60 m, while specimens greater than 40 mm SL have only been taken in trawls fished to 490 m and deeper.

Minimal catch data suggest that during the day, *B. pyrsobolus* is not found in the upper 500 m of the water column, but that at night small specimens (less than about 25 mm SL) may migrate into the upper 120 m of the water column (Fig. 54).

Geographic distribution

Bolinichthys pyrsobolus is an oceanic, mesopelagic species. In the western Indian Ocean, it is reported off the African coast between 12°N-10°S. It is been taken off Sri Lanka, in the southern Gulf of Bengal and in the eastern sector of the Indian Ocean between 11°N-21°S (Fig. 55). In the Pacific Ocean, it occurs in the South China Sea, Sulu Sea, Banda Sea, Bismark Sea and northern Coral Sea regions, and is known from the equatorial Pacific between 159°E-139°W. There is a single record off Japan (35°N). There are also records in the eastern North, Central and South Pacific (see

Remarks below). The data indicate that the geographic and depth distributional ranges of the known records are restricted to the more productive, but less saline waters of the Indo-Pacific and South-east Asian Seas, where dissolved oxygen concentrations at 200 m are less than 3.6 ml.litre⁻¹ (Fig. 55).

Remarks

The specimen, identified as *B. blacki* (SIO 76-104: 30°56.7'N, 144°48'W) should be treated with reservation. LACM specimens (33°-18°N, 108°-121°W) identified as *B. pyrsobolus* from eastern North Pacific are tentatively included, as more than one species could be involved. Similarly, specimens reported as *B. pyrsobolus* by Parin *et al.* (1973) from the eastern South Pacific are also tentatively included; in more recent work Parin *et al.* (1990a) have only reported *B. longipes*, *B. photothorax* and *B. supralateralis* from this region. Further investigation of this material is warranted, since all these records fall within the proposed distributional parameters.

BOLINICHTHYS SUPRALATERALIS (PARR, 1928)

(Figs 56-69, Tabs I-IV)

Synonymy

Lampanyctus supralateralis Parr, 1928: 94-95, fig. 12 (23°42'N, 76°43'W, 7000 ft w.o.). Holotype: BOC 2229; 3 paratypes: BOC 2228 (2 spec.), 2230 (1 spec.).

Lampanyctus supralateralis: Beebe, 1937: 204; Grey, 1955: 289; Bullis and Thompson, 1965: 28; Eschmeyer, 2008.

Lampanyctus (Lepidophanes) supralateralis: Fraser-Brunner, 1949: 1091, fig.

Lampanyctus superlateralis: Grindley and Penrith, 1965: 283.

Lampanyctus pyrsobolus (non Alcock, 1890): Grindley and Penrith, 1965: 283 (*partim*); Backus *et al.*, 1969: 95, tab. 5 (*partim*).

Lepidophanes supralateralis: Bullis and Thompson, 1965: 29; Backus *et al.*, 1970: 191; Gibbs *et al.*, 1971: 114, 134; Hulley, 1972b: 241, fig. 2.

Bolinichthys supralateralis: Paxton, 1972: 47; 1979: 6; Clarke, 1973: 422, 424-425; McGinnis, 1974: 133, figs. 31, 58; 1982: 40, 69, 94, fig. 28; Moser and Ahlstrom, 1974: 409, fig. 11d; Johnson, 1975: 53-56, 58-59, figs. 1b, 3d, 3e, 3f; Badcock and Merrett, 1976: 42; Wisner, 1976: 199, 200-202, tabs. 40-41; fig. 188; Nafpaktitis *et al.*, 1977: 232-234, figs. 162-163; Backus *et al.*, 1977: 267, 274-275, 277; Krueger *et al.*, 1977: 783; Nafpaktitis, 1978a: 6; Becker, 1978: fig. 2 (1); 1983: 213, figs. 50 (a), 99 (4); Gjøsæter and Kawaguchi, 1980: 25, tab. 3.6; Hulley, 1981: 230-231, fig. 104; 1984a: 435-436, fig.; 1984b: 68; 1986b: 241, tab. 7; 1990: 402; 1992: tabs. 2, 7-8; Brandt, 1983: tab. 2; Fujii, 1983: 186, fig.; Hopkins and Lancraft, 1984: 155; Richards, 1984: 14; McKelvie, 1985b: tab. 3; Griffiths and Wadley, 1986: tab. 2; Karnella, 1987: 61-62; Gartner *et al.*, 1987: tab 3; 1989: 88, tabs. 1, 6; Paxton *et*

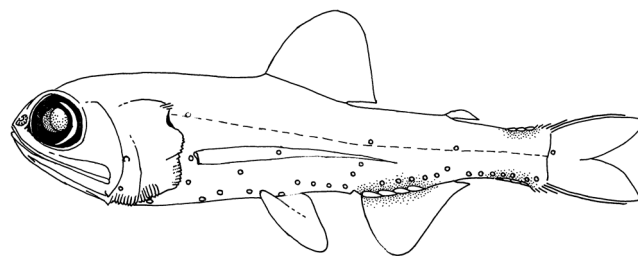


Figure 56. - *Bolinichthys supralateralis*. Lateral view (25 mm SL: after Hulley, 1986).

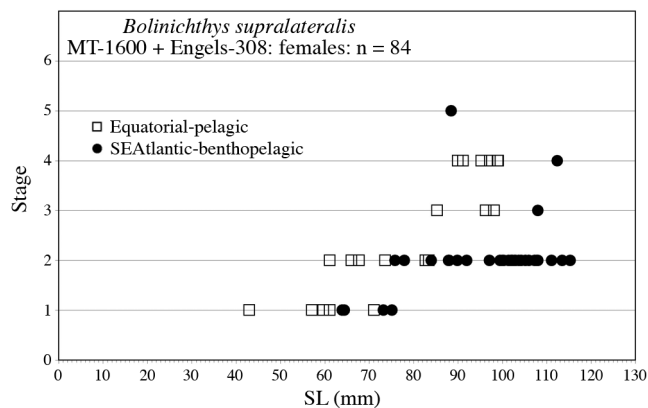


Figure 57. - *Bolinichthys supralateralis*. Relationship of sexual maturity to standard length (SL) in pelagic and benthopelagic specimens.

al., 1989: 255; Parin *et al.*, 1990a: 202; van der Spoel and Bleeker, 1991: 96, tab. 1; Craddock *et al.*, 1992: tabs. 1-2; Hulley and Lutjeharms, 1995: 190; Smale *et al.*, 1995: 42, pl. 17; Linkowski, 1996: tab. 1; Olivar *et al.*, 1999: 110, tab. 1; Allué *et al.*, 2000: 53; Wang and Chen, 2001: 103, 113-114, tabs. 1-3, fig. 8, 10, 30; Moser and Watson, 2001: tabs. 1-3; Craddock and Hartel, 2002: 950; Brito *et al.*, 2002: 113; Moore *et al.*, 2003: 198; Fock *et al.*, 2004: 969, tab. 3; Hoese *et al.*, 2006: 511; Eschmeyer, 2008; Hulley and Paxton, in press.; Barrère *et al.*, in press.

Lepidophanes sp.: Kotthaus, 1972b: 34, figs. 280-285.

? *Bolinichthys* sp.: Nellen and Ruseler, 2004: tab. 1.

Remarks on synonyms

Specimens from NW Cochín described as *Lepidophanes* sp. by Kotthaus (1972b) may be referred to this species because VLO is midway between the lateral line and the pelvic fin; and the gill-raker count is 6-7 + 1 + 15.

Meristics

D 13 (12-14); A 14 (12-15); P 13 (12-14); AO 6 (4-7) + 4 (3-5), total 10 (8-11); GR 6 (5-7) + 1 + 12-13 (11-15), total 19-20 (18-22).

Description

Eye large, aphakic space present; crescent of white tis-

sue on posterior half of iris. Large, re-curved preopercular spine absent. Posterodorsal margin of operculum anteriorly concave, distance between cusps about twice length of base of pectoral fin; posterior margin of subopercle serrate; ventral margin of interopercle serrate (in specimens longer than 30 mm SL). Origin of dorsal fin about on vertical through outer base of pelvic fin; origin of anal fin behind vertical through posterior end of base of dorsal fin; pectoral fins long, reaching at least to AOa₃; pelvic fins reaching to origin of anal fin; adipose origin in advance of end of base of anal fin.

Vn at anterior border of eye, between nasal rosette and anterior edge of pupil. Small post-ocular photophores absent. Op₁ below level of posterior angle of mouth, just above ventral margin of posterior flange of preopercle; Op₂ larger, at or above level of ventral margin of orbit. PLO at, immediately below or just above lateral line. PVO₁ at, slightly behind or slightly in advance of PVO₂, which is in front of middle of base of pectoral fin. 5 PO; with PO₃ raised above line through centres of PO₁-PO₂; with PO₄ dorsal to level of PVO₁, and somewhat nearer to PO₅ than PO₃; and with PO₅ in front of outer pelvic base. VLO 3-5 photophore diameters below lateral line, posterior to vertical through outer pelvic base. 5 VO; with VO₂ elevated, but distinctly below line connecting PO₄-SAO₁; and with VO₂-VO₅ in a straight, oblique, descending line. SAO₁ posterior to vertical through VO₄, at about level of PO₄; with SAO₂ about on vertical through origin of anal fin, usually closer to SAO₁ than SAO₃; and with SAO₃ at or just above lateral line, posterior to vertical through origin of anal fin. AO series divided into AOa and AOp, with AOa₁ and last AOa level, sometimes raised to elevated; AOp evenly spaced and all posterior to end of anal fin. 2 Pol (by definition), with Pol₁ elevated above AOa series, about on vertical through middle of base of adipose fin; and with Pol₂ at or just above lateral line, behind vertical through base of adipose fin. 2+1 Prc; with Prc₂ 1 photophore diameter posterodorsad to Prc₁; and with Prc₃ well behind Prc₂ and above level of lateral line. Minute secondary photophores on trunk. Supracaudal luminous organ consisting of 2-3 luminous, scale-like patches; infracaudal organ consisting of 3-6 luminous, scale-like patches, extending anteriorly from procurent caudal rays to at least level of last AOp, and sometimes to level of AOp₂. Luminous tissue on top of head and on sides of body absent. Scale-like patch of luminous tissue at base of pelvic fin absent. No luminous patches along base of dorsal fin; 3-5 elongate, luminous patches along base of anal fin, commencing in front of AOa₁ and extending posteriorly to about AOa₃-AOa₄.

Size and maturation

Maximum size to 117 mm SL; females sexually mature (Stages IV-V) from about 90 mm SL (Fig. 57), both for pelagic and benthopelagic specimens. Gravid females have been taken in January (Réunion Is., Indian Ocean), February

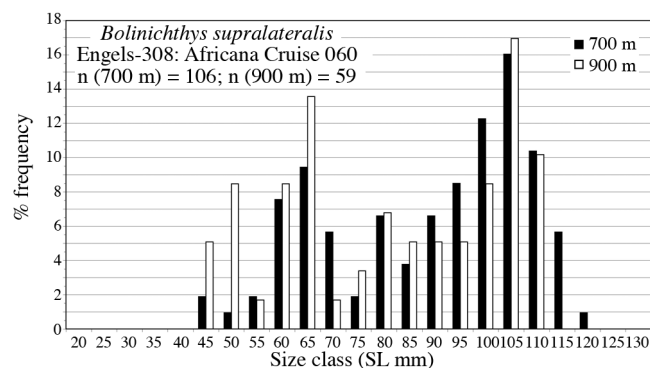


Figure 58. - *Bolinichthys supralateralis*. Length-frequency histograms for specimens from 700 m and 900 m depth strata.

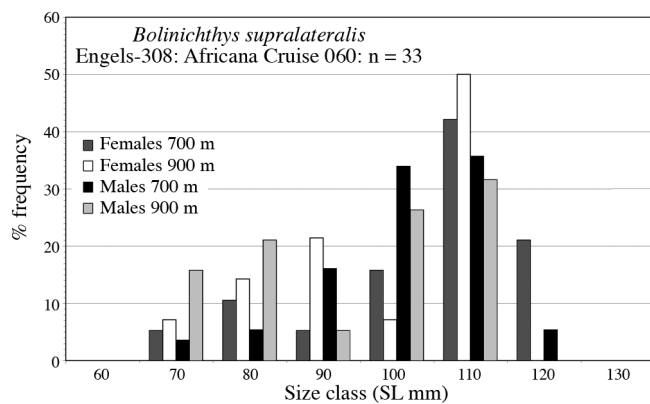


Figure 59. - *Bolinichthys supralateralis*. Length-frequency histograms for males and females from 700 m and 900 m depth strata.

(Equatorial and SW Atlantic), March (SE Atlantic) and April (NE and SE Atlantic), suggesting a late summer spawning period in all oceans. However, near Bermuda and on the basis of limited data, Karnella (1987) suggested that spawning occurs in late spring to early summer.

Size-frequency data for benthopelagic specimens from the eastern South Atlantic slope region are given in figures 58-59. Size ranges were similar in samples from the 700 m and 900 m depth strata, and there appeared to be no depth-segregation by sex. Further, four size-classes were evident within the size range of specimens sampled by the Engels-308 (see below). Sexual dimorphism in size reported by Karnella (1987) for specimens near Bermuda may be a sampling artifact; it is not evident in the SE Atlantic slope populations, where both females (maximum size 115.3 mm) and males (maximum size 114.7 mm) are present in the largest size-class (Fig. 59).

Karnella (1987) suggested that near Bermuda the breeding season is restricted, since small specimens (< 20 mm SL) were only taken in late spring-early summer. Larger specimens (> 50 mm SL) were caught in February, April, June and August, but may have been present throughout the year. Specimens caught in late summer near Bermuda com-

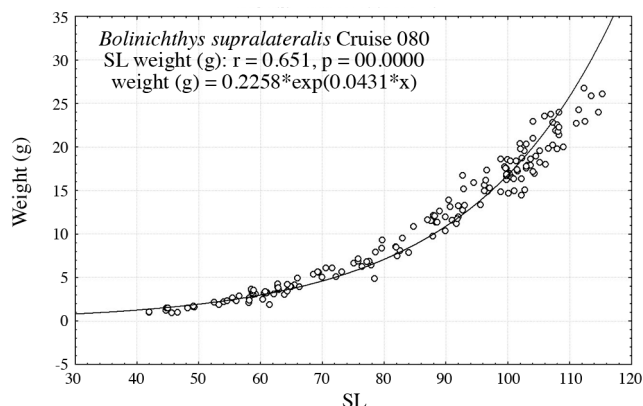


Figure 60. - *Bolinichthys supralateralis*. Correlation between wet weight (g) and standard length (SL).

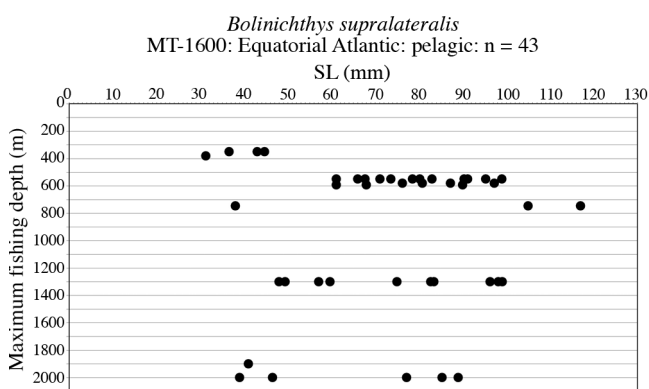


Figure 61. - *Bolinichthys supralateralis*. Variation of standard length (SL) with maximum fishing depth of haul.

prise at least three year-classes: 12-20 mm class = recruits; 35-74 mm = one year-old; 91-97 mm = at least two year-old. However, the intermediate group may itself have two size classes (35-54 mm and 56-77 mm). On the basis of Karnella's observations above, data on eastern South Atlantic material suggest the possibility of five year-classes. Four size classes (40-50 mm; 60-70 mm; 80-85 mm; and 95-115 mm) are apparent (Fig. 58) in the MT-1600 data sets, and this gear is a poor sampler of specimens less than 30 mm SL.

The correlation ($r = 0.956$) of wet weight with SL for the SE Atlantic specimens is given in figure 60. Wider dispersion about the 95% confidence line with increasing SL is probably due to increasing variability in wet weight with increasing wetted surface area.

Depth distribution

Unlike other species in the genus, *B. supralateralis* exhibits the characteristics of both an oceanic, mesopelagic species, and a pseudo-oceanic, benthopelagic species.

Moore *et al.* (2003) have indicated that the species is mesopelagic, occurring between 375-750 m during the day (peak abundance at 450-500 m) and 40-650 m at night (peak abundance at 100 m), but that large individuals below 500 m

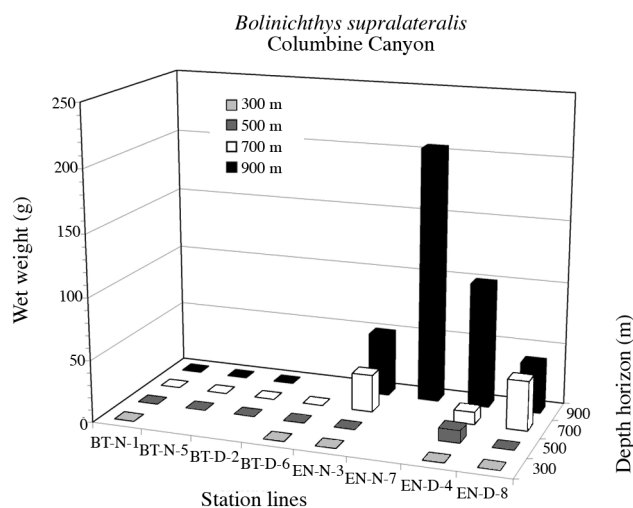


Figure 62. - *Bolinichthys supralateralis*. Columbine Canyon: variation of wet weights for standardized 180' Bottom Trawl and Engels-308 hauls. BT = 180' Bottom Trawl; EN = Engels-308 Trawl; D = day hauls; N = night hauls; 1-8 = lines of 4 stations fished at 300 m, 500 m, 700 m, 900 m.

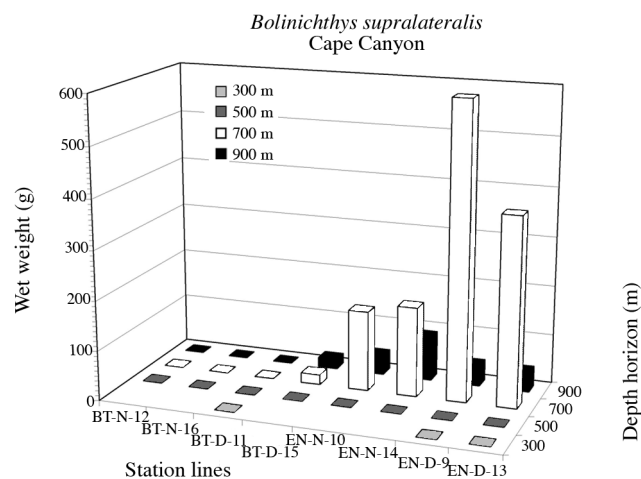


Figure 63. - *Bolinichthys supralateralis*. Cape Canyon: variation of wet weights for standardized 180' Bottom Trawl and Engels-308 hauls. BT = 180' Bottom Trawl; EN = Engels-308 Trawl; D = day hauls; N = night hauls; 1-8 = lines of 4 stations fished at 300 m, 500 m, 700 m, 900 m.

at night may be non-migratory.

Hulley (1981) regarded the species as having a questionably mesopelagic, holotropical distribution pattern in the Atlantic Ocean; Backus *et al.* (1977) and Nafpaktitis *et al.* (1977) suggested a mesopelagic, tropical-subtropical distribution in the Atlantic; and near Bermuda, Karnella (1987) proposed a questionably tropical-subtropical species, with small specimens (12-16 mm) undertaking diel migration from 450 m (day) to 210-300 m (night), and larger specimens (> 35 mm) being found below 650 m (both day and night). Paxton *et al.* (1989) have indicated an oceanic, mesopelagic distribution around Australia. Hulley and Paxton

(in Press) record that the species is oceanic, with small specimens being mesopelagic in depths of 375-750 m (day) and 40-650 m (night); but with larger specimens being benthopelagic, non-migrators.

Depth distributions of specimens taken with an Engels MT-1600 in the Equatorial Atlantic at night are given in figure 61. No specimens were caught in the upper 350 m of the water column; juveniles (< 50 mm SL) were taken below 350m; and adults (> 60 mm SL) only below 550 m. However, it must be emphasized that even with a cod-end liner the MT-1600 is an inadequate sampler of fishes smaller than about 30 mm SL.

Off Namibia, the species has been taken in bottom trawls between 534-615 m (Allué *et al.*, 2000). Similarly, catch data (Figs. 62-63) from *Africana* Cruise 60 off South Africa suggest that *B. supralateralis* is also closely associated with the continental slope region. During the day and in bottom trawls (German BT-180' high-lift), the species was taken in the 700 m and 900 m depth strata on a single line of stations in the Cape Canyon; and was caught in one daylight haul in the 500 m depth stratum in the Columbine Canyon (Fig. 62). It was absent in bottom trawls during the night. However, during both day and night sampling with an Engels-308 net (fished 10 m above the bottom), the species was taken at all stations in the 700 m and 900 m depth strata and in both canyons (Figs. 62-63). The data also indicate that in the Cape Canyon (Fig. 63), *B. supralateralis* was more abundant in hauls from the 700 m depth stratum than from the 900 m depth stratum, while in the Columbine Canyon was more abundant in the 900 m depth stratum (Fig. 62). There were day-night

differences in abundances in hauls from the 700 m and 900 m depth strata in the Cape Canyon, but this was not evident in samples from the Columbine Canyon (Figs. 62-63). Such differences may be a sampling artifact. During the cruise, *B. supralateralis* was never taken in the Engels-308 pelagic hauls (5) fished at night in the upper 55-517 m of the water column. This suggests that in the eastern South Atlantic and at this time of the year at least, large specimens are distributed above the bottom and mainly between 700-900 m. They are basically non-migrators.

To summarize all of the above, the data indicate that non-migrating adults are associated with continental and island slopes; and imply that smaller, vertically migrating juveniles, which are found further offshore, may represent "downstream" occurrences. There can be no doubt that Karmann's (1987: 61) small, pelagic specimens from the Bermuda Ocean Acre expeditions are related to the close proximity of that island's slope regions to the sampling stations. Further, his records of adult specimens, which were caught in Engels hauls rather than by IKMT's, were from much farther south, and probably represent "downstream" specimens from sources other than the Bermuda slope (see below).

Geographic distribution

The geographic distribution of *Bolinichthys supralateralis* is discussed below within the context of this continental / island slope association and downstream occurrences of smaller migratory specimens.

In the equatorial and western North Pacific (Fig. 64), *B. supralateralis* has been recorded from the slope regions

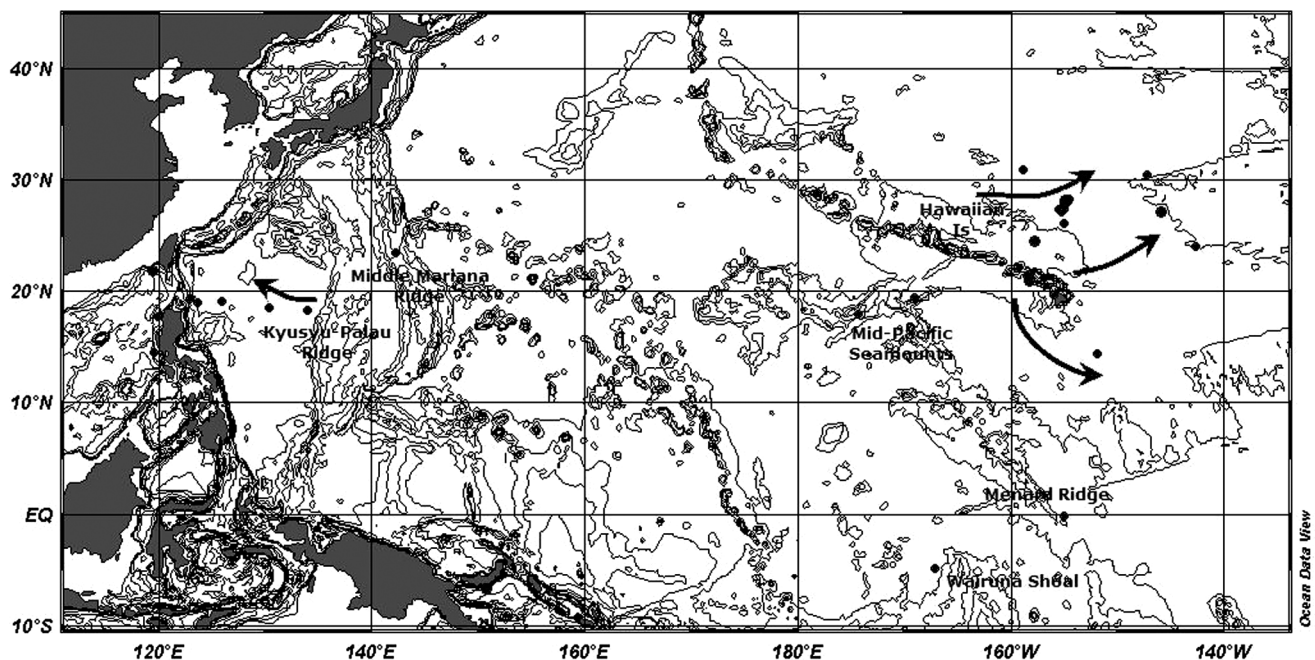
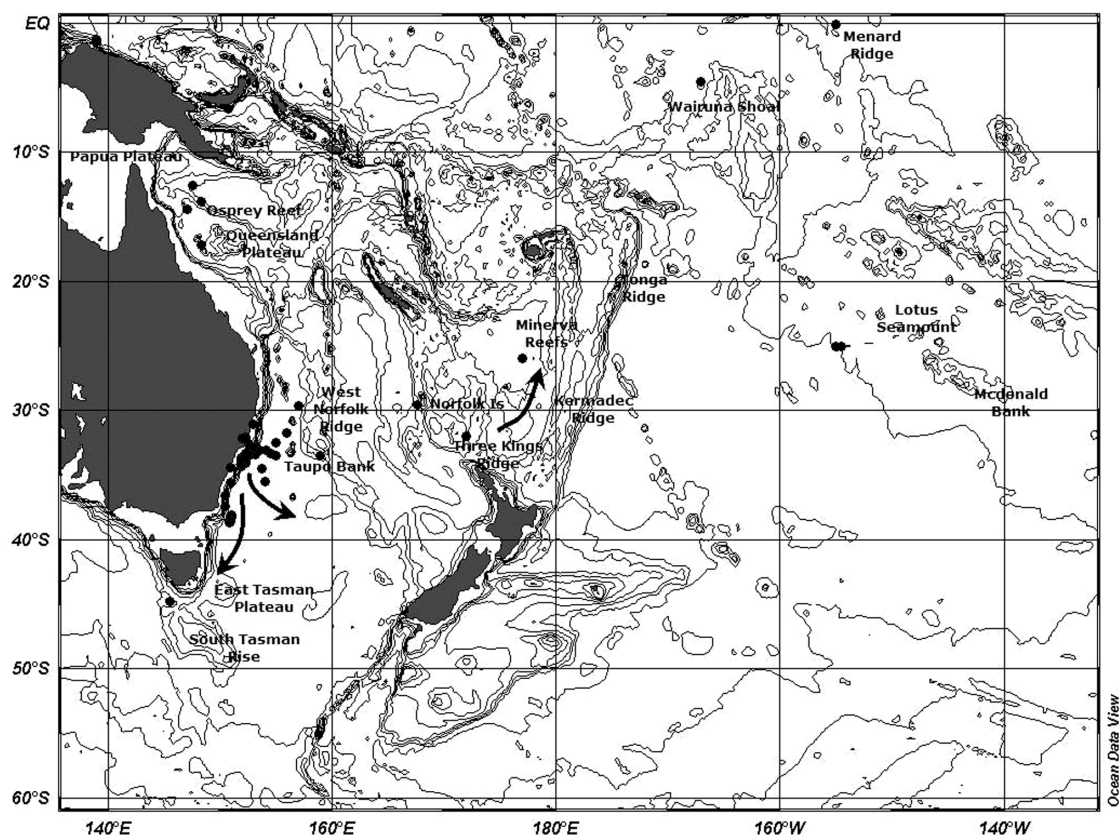
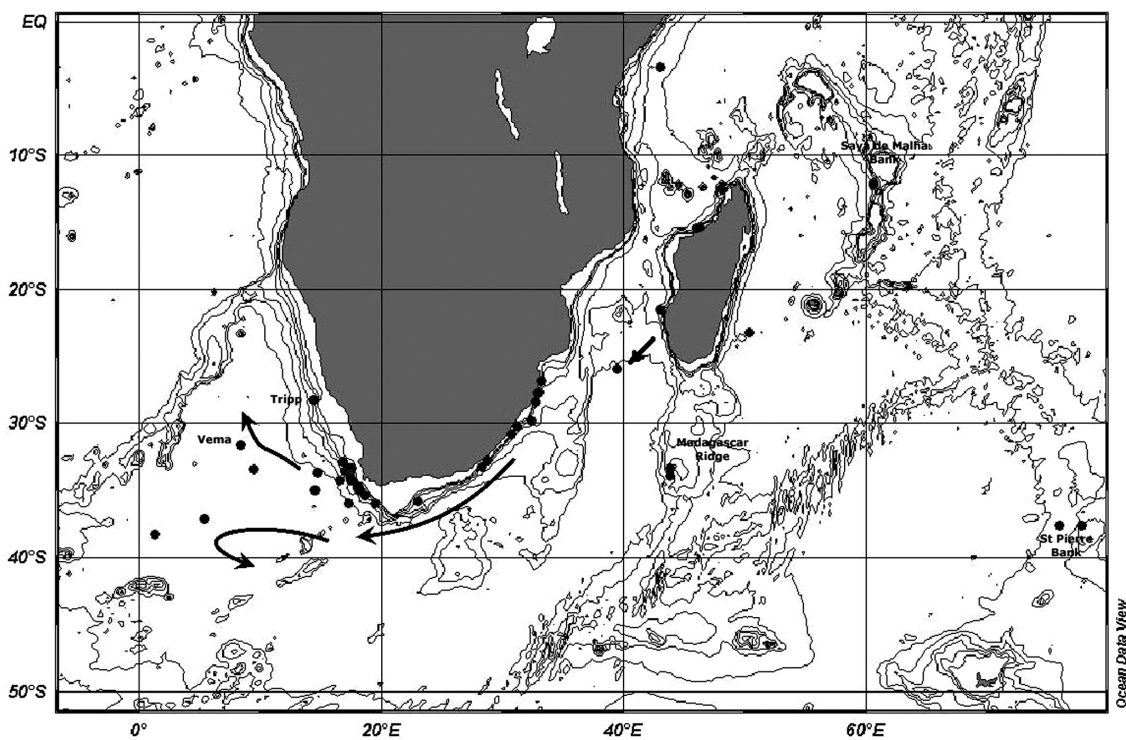


Figure 64. - *Bolinichthys supralateralis*. Distribution in the equatorial and western North Pacific Ocean.

Figure 65. - *Bolinichthys supralateralis*. Distribution in the western South Pacific Ocean.Figure 66. - *Bolinichthys supralateralis*. Distribution in the western South Indian Ocean.

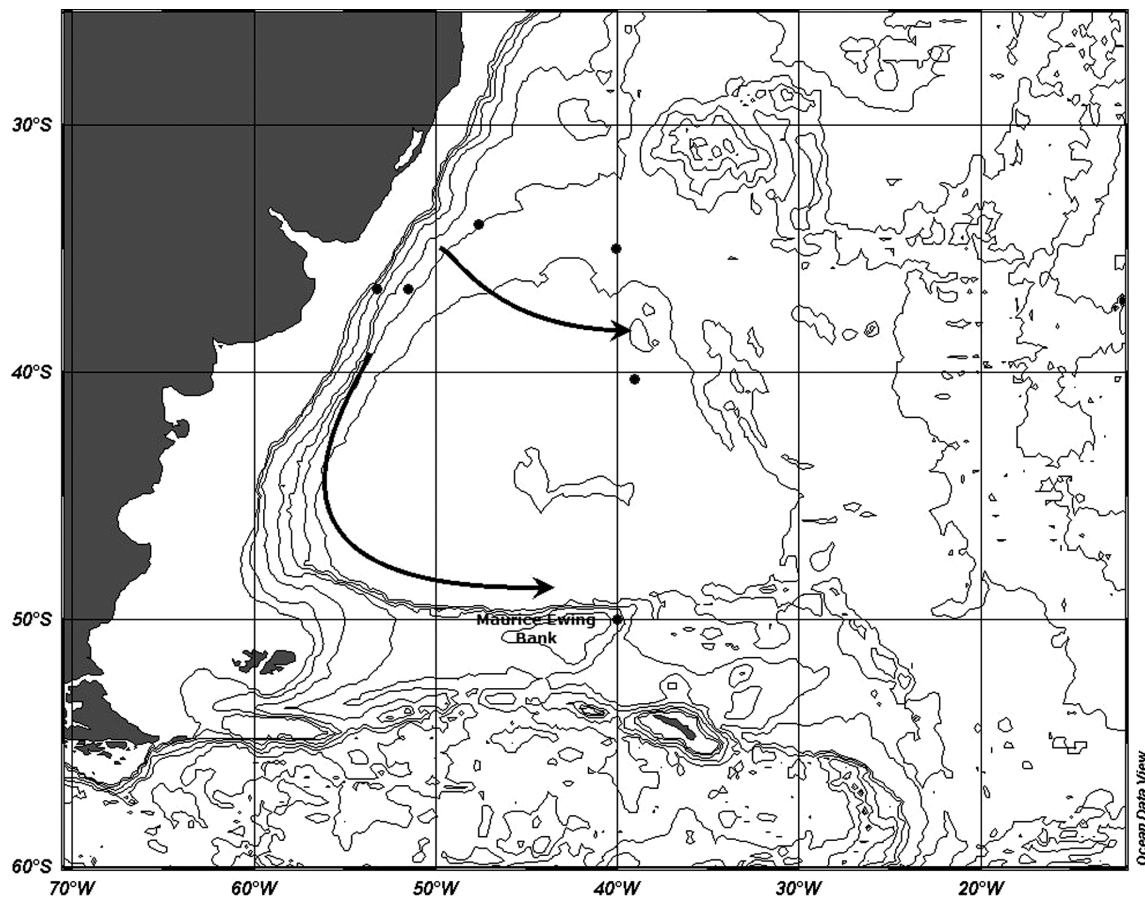


Figure 67. - *Bolinichthys supralateralis*. Distribution in the western South Atlantic Ocean.

off the north coast of Irian Jaya; from the Bohol Sea; the eastern Sulu Sea; the South China Sea at about 07°N, 114–115°E; from off the east and west slopes of Luzon; off the south-west coast of Taiwan; and from the Middle Mariana Ridge. Around Tungsha Islands, the species was taken mainly in bottom trawls on the slope in depths between 458–754 m (Wang and Chen 2001: fig. 8). The off-shore records east of Luzon may represent downstream occurrences of smaller specimens. The species has also been taken near the Wairuna Shoal, the Menard Ridge and over the mid-Pacific Seamounts. There are records from the slopes of the Hawaiian Islands with associated possible downstream occurrences to the east and south-east of the island chain. The species has not been recorded east of about 143°W in the North Pacific, although there is a single, unsubstantiated record off the coast of Columbia at 01°52.0'N, 080°04.0'W (SIO 72-344: surface, dipnet + light: not included in Fig. 64).

In the western South Pacific (Fig. 65), *B. supralateralis* occurs on the southern slope of New Britain, and southwards along the eastern Australian slope (including Osprey Reef and Queensland Plateau) to about 38°S. Specimens from the south-west slope of Tasmania at about 45°S, 145°E may represent downstream occurrences in the East Austral-

ian Current eddy system. Records off-shore of the New South Wales slope may likewise represent downstream occurrences associated with the development of the Tasman Front (http://www.marine.csiro.au/LeafletsFolder/images/eac_scemlg.gif). The species has also been recorded from the West Norfolk Ridge, Taupo Bank, Norfolk Island and Three Kings Ridge areas. Records at about 26°S, 177°E; 25°S, 155°W; and 35°S, 125°W may represent downstream occurrences associated with the Kermadec Ridge / Minerva Reefs, the Lotus Seamount / Macdonald Bank, and the Foundation Seamounts respectively. The species has also been reported from the Sala y Gomez Ridge region at 25°S, 093°W (Parin *et al.*, 1990a).

In the Indian Ocean (Fig. 66), *B. supralateralis* has generally not been recorded north of the Equator, but east of the Mid-Indian Ocean Ridge there is a single record of the species above the slope of south-western Sumatra at about 03°S 100°E. This specimen (ZMUC P 2363757) should now be referred to *B. pyrsobolus* (see below). In the western sector, *B. supralateralis* has been found off the coast of Kenya; over the Saya de Malha Bank; off the east and west coasts of Madagascar, including Réunion Island (Barrère *et al.*, in press); over the Madagascar Ridge (Parin *et al.*, 1993); and the east coast of South Africa to about 35°S. Isolated records

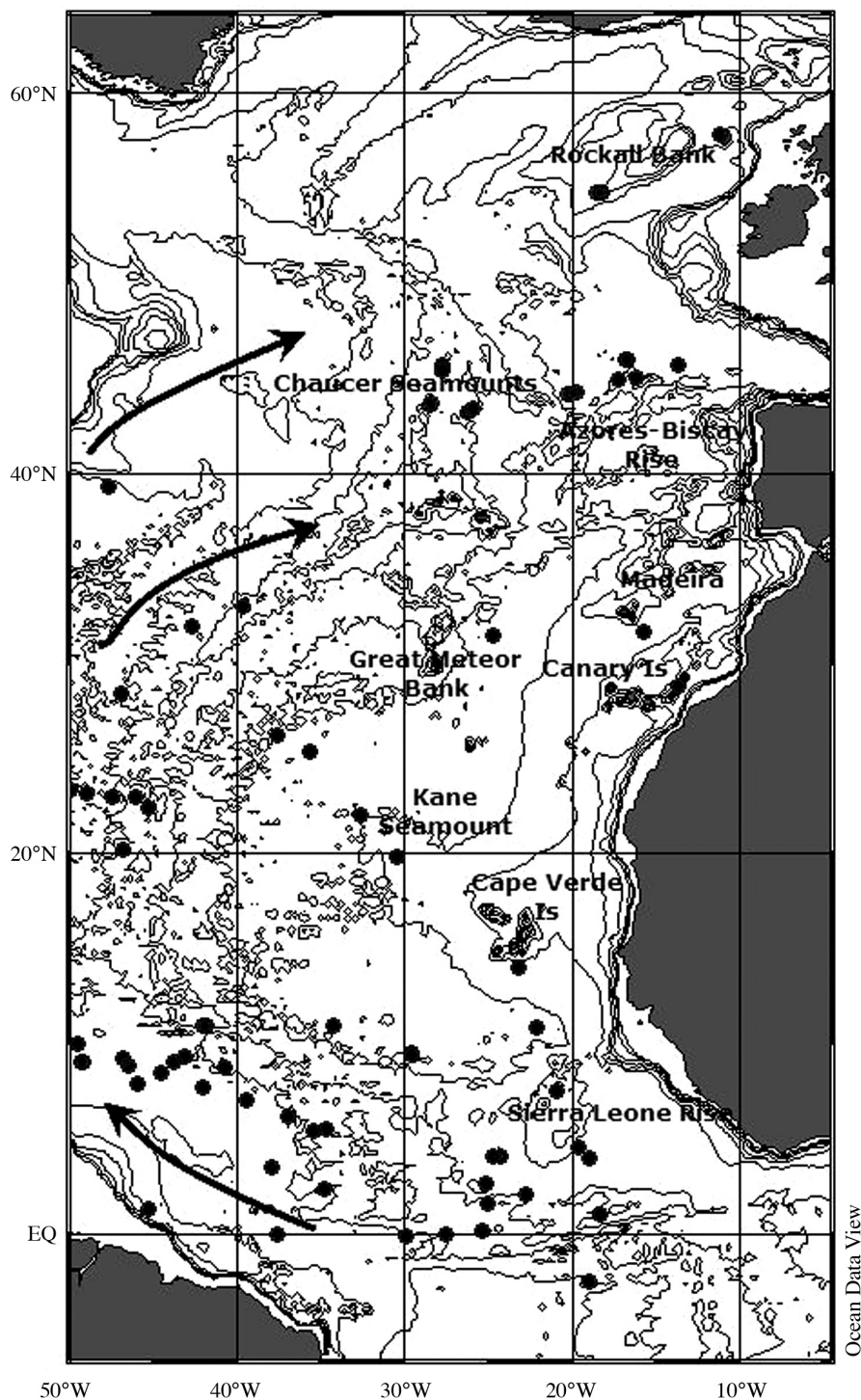


Figure 68. - *Bolinichthys supralateralis*. Distribution in the equatorial and eastern North Atlantic Ocean.

in the eastern South Atlantic at about 37–38°S, 001–005°E could represent downstream occurrences associated with the Agulhas Current Retroflexion (Hulley and Lutjeharms, 1995). Although *B. supralateralis* has been recorded from St Paul and New Amsterdam Islands and the St Pierre Bank, it has not been taken farther eastwards off the Western Austral-

ian continental slope.

The species is common over the slope regions of the west coast of South Africa and has been taken at the Tripp and Vema Seamounts (Fig. 66). While there is an off-shore, downstream component to the distribution in this region associated with the flow dynamics of the Benguela Current,

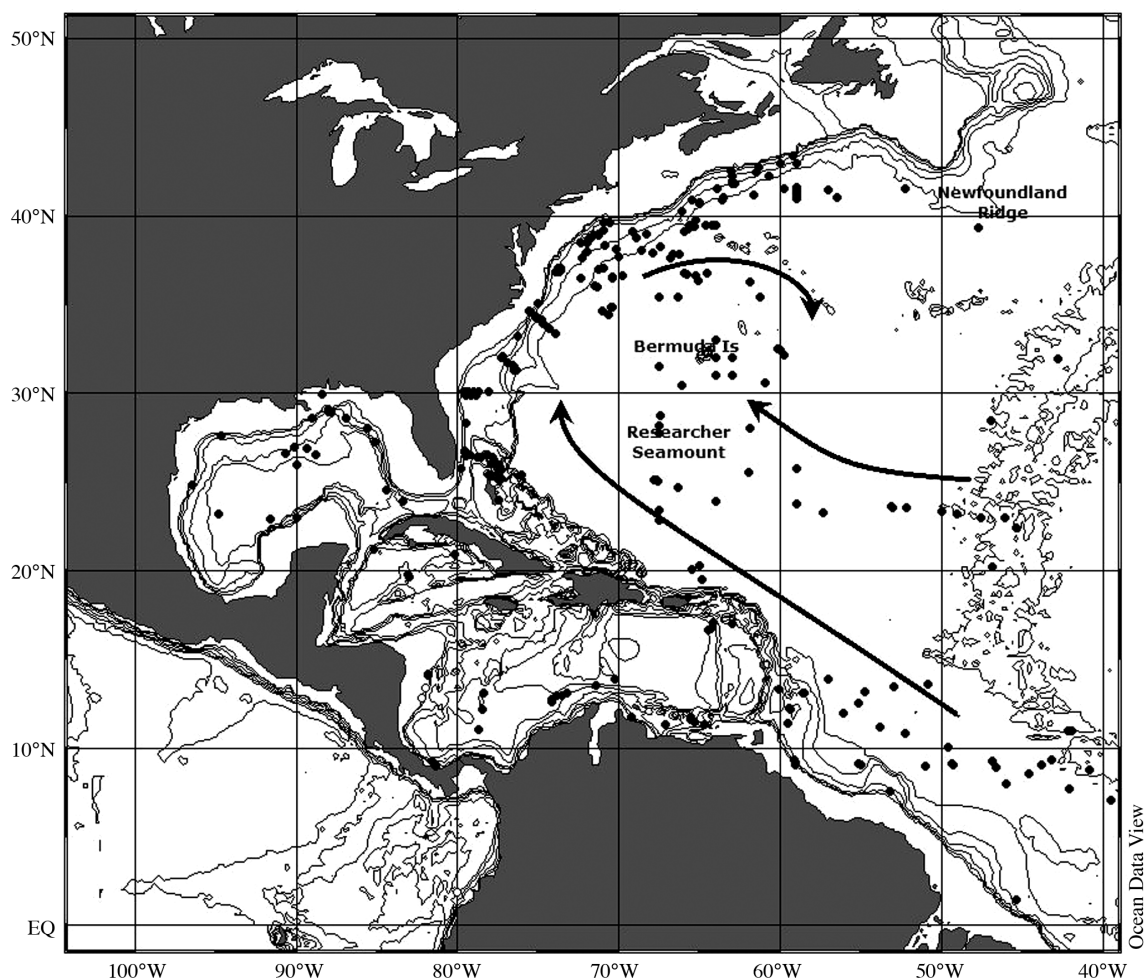


Figure 69. - *Bolinichthys supralateralis*. Distribution in the western North Atlantic Ocean.

there appear to be no records north of the Walvis Ridge in the eastern Atlantic, and the species has never been reported from the Gulf of Guinea.

In the western South Atlantic (Fig. 67), *B. supralateralis* occurs above the Argentinian slope south of about 34°S and over the Maurice Ewing Bank, with oceanic downstream records associated with the eastward flow of the Brazil Current at about 35-40°S (Hulley, 1981).

In the eastern North Atlantic (Fig. 68), *B. supralateralis* has been taken at Rockall Bank; over the Chaucer Seamounts and Azores-Biscay Rise; west of the Great Meteor and Kane Seamounts; off Madeira, the Canary and Cape Verde islands; and above the Sierra Leone Rise and Mid-Atlantic Ridge system.

In the western North Atlantic (Fig. 69), the species has been taken over the continental and island slope regions between about 44°N and 0°, as well as over slope regions in the Caribbean Sea and the Gulf of Mexico. Vinichenko (1997) has reported the species from the slopes of the Corner Rising Seamount and Moore *et al.* (2004) from the

New England Seamount chain. Records from south-east of Bermuda and the Researcher Seamount may be associated downstream components from the Mid-Atlantic Ridge system, while there may be similar downstream components off the slopes of the eastern American seaboard.

Remarks

The specimen from off Sumatra (ZMUC P 2363757; 14 mm SL) identified as *B. supralateralis* should be referred to *B. pyrsobolus*, because of the following: VLO 2-5 photophore diameters below lateral line; VO₂-VO₅ distinctly angulate; and VLO closer to lateral line than to pelvic base.

Acknowledgements. - The senior author (PAH) wishes to express his sincere gratitude to the Director, Muséum national d'Histoire naturelle (Paris), and to the Directors, Laboratoire d'ichtyologie générale et appliquée (MNHN-Paris), namely: Professors J. Daget, R. Billard and F.J. Meunier, for allowing him to study lanternfish specimens in their collection with the support of a series of research grants between 1991-2002. Without their keen interest, none of this work would have been possible. Initial funding for laboratory-based investigations in South Africa was obtained through a

research grant from the National Research Foundation, South Africa.

We are extremely grateful to John Paxton (AMS) for willingly furnishing us with unpublished data; for undertaking the examination of material both at AMS and MCZ; and for his critical discussion of ideas during his examination of parts of various drafts of the manuscript. Like-wise, Karsten Hartel (MCZ) and Jørgen Nielsen (ZMUC) re-examined numerous specimens and supplied us with significant data input. All their efforts are hugely appreciated.

The authors also wish to thank the following people for their assistance in providing data on the specimens in their collections and/or other information: Australian Museum (Sydney) - Mark McGrouther; California Academy of Sciences (San Francisco) - Tomio Iwamoto, Jon Fong, Dave Catania; CSIRO (Hobart) - John Pogonoski, Peter Last; Field Museum (Chicago) - Mary Anne Rogers, Philip Willink; Zoologisches Museum (Berlin) - Peter Bartsch; Institute of Oceanology (Moscow) - Nik Parin, Sergei Evseenko, Artem Prokofiev; Muséum d'Histoire Naturelle (La Rochelle) - Jean-Claude Quéro; Muséum d'Histoire Naturelle (Saint-Denis, Réunion) - Sonia Ribes-Beaudemoulin; Muséum National d'Histoire Naturelle (Paris) - Jean-Claude Hureau, Catherine Ozouf-Costaz, Patrice Pruvost; Natural History Museum of Los Angeles County (Los Angeles) - Jeff Seigel; Royal Ontario Museum (Toronto) - Rick Winterbottom, Erling Holm; Scripps Institution of Oceanography (La Jolla) - Cindy Klepadlo, HJ Walker; South African Institute of Aquatic Biodiversity (Grahamstown) - Eric Anderson, Ofer Gon; The Natural History Museum (London) - Carole Baldwin, Oliver Crimmen; University of Cape Town (Cape Town) - Johann Lutjeharms. Finally, the authors wish to acknowledge the Alfred-Wegener Institute (Bremmerhaven) for allowing us the use of the ODV program and the associated data sets.

REFERENCES

- AHLSTROM E.H., MOSER H.G. & O'TOOLE M.J., 1976. - Development and distribution of larvae and early juveniles of the commercial lanternfish *Lampanyctodes hectoris* (Günther) off the west coast of southern Africa, with a discussion of phylogenetic relationships of the genus. *Bull. South. Calif. Acad. Sci.*, 75(2): 138-152.
- ALBUQUERQUE R.M., 1954. - Peixes de Portugal e ilhas adjacentes. Chavas para a sua determinação. *Port. Acta Biol.*, 5: i-xvi, 1.
- ALCOCK A.W., 1890. - Natural history notes from H.M. Indian marine survey steamer 'Investigator'. No. 16. On the bathyhal fishes collected in the Bay of Bengal during the season 1889-1890. *Ann. Mag. Nat. Hist.*, 6(33): 197-222.
- ALLUÉ C., LLORIS D. & MESEGUER S., 2000. - Colecciones biológicas de Referencia (1982-1999) del Instituto de Ciencias del Mar (CSIC): Catálogo de Peces. 198 p. Barcelona: Instituto del Ciencias del Mar.
- ANGEL M.F. & VERRIER M.L., 1931. - Étude de quelques poissons des grandes profondeurs; Étude systématique. *Ann. Inst. Océanogr. Monaco*, 10(5): 119-128.
- AUGUSTYN C.J. & HULLEY P.A., 1988. - In search of alternative deep-water resources. *South Afr. Shipping News Fish. Ind. Rev.*, 43: 57-59.
- BACKUS R.H., MEAD G.W., HAEDRICH R.L. & EBELING A.W., 1965. - The mesopelagic fishes collected during Cruise 17 of the R/V 'Chain', with a method for analyzing faunal transects. *Bull. Mus. Comp. Zool. Harvard Univ.*, 134(5): 139-158.
- BACKUS R.H., CRADDOCK J.E., HAEDRICH R.L. & SHORES D.L., 1969. - Mesopelagic fishes and thermal fronts in the western Sargasso Sea. *Mar. Biol.*, 3(2): 87-106.
- BACKUS R.H., CRADDOCK J.E., HAEDRICH R.L. & SHORES D.L., 1970. - The distribution of mesopelagic fishes in the equatorial and western North Atlantic. *J. Mar. Res.*, 28(2): 179-201.
- BACKUS R.H., CRADDOCK J.E., HAEDRICH R.L. & ROBINSON B.H., 1977. - Atlantic mesopelagic zoogeography. In: *Fishes of the Western North Atlantic*. 7 (Gibbs Jr. R.H., Berry F.H., Bölle J.E., Cohen D.M., Collette B.B., Eschmeyer W.N., Mead G.W., Merriman D. & Pietsch T.W., eds.). *Mem. Sears Found. Mar. Res.*, 1(7): 266-287.
- BADCOCK J., 1970. - The vertical distribution of mesopelagic fishes collected on the SOND Cruise. *J. Mar. Biol. Ass. UK*, 50: 1001-1044.
- BADCOCK J. & MERRETT N.R., 1976. - Midwater fishes in the eastern North Atlantic. I. Vertical distribution and associated biology in 30°N, 23°W, with developmental notes on certain myctophids. *Progress Oceanogr.*, 7(1): 3-58.
- BARNETT M.A., 1983. - Species structure and temporal stability of mesopelagic fish assemblages in the Central Gyres of the North and South Pacific Ocean. *Mar. Biol.*, 74(3): 245-256.
- BARNETT M.A., 1984. - Mesopelagic fish zoogeography in the central tropical and subtropical Pacific Ocean: species composition and structure at representative locations in three ecosystems. *Mar. Biol.*, 82(2): 199-208.
- BARRÈRE A., MULOCHAU T., DURVILLE P., QUOD J.-P., QUÉRO J.C. & SPITZ J., in press. - Les poissons tués par l'éruption d'avril 2007 du Piton de la Fournaise. *Borbonica*.
- BEEBE W., 1937. - Preliminary list of Bermuda deep-sea fishes. *Zool.*, NY, 22: 197-208.
- BEEBE W. & VAN DER PYL M., 1944. - Eastern Pacific Expeditions of the New York Zoological Society. XXXIII. Pacific Myctophidae (Fishes). *Zool.*, NY, 29(2): 59-95.
- BECKER V.E., 1967a. - Luminous anchovies (Fam. Myctophidae). *Tr. Inst. Okeanol.*, 7(3): 143-181 (in Russian).
- BECKER V.E., 1967b. - The lanternfishes (Myctophidae) from the 'Petr Lebedev' Atlantic Expeditions 1961-1964. *Tr. Inst. Okeanol.*, 84: 84-124. (in Russian).
- BECKER V.E., 1978. - New species of the genus *Bolinichthys* (Myctophidae, Osteichthyes) from the South Pacific Ocean. *Tr. Inst. Okeanol.*, 111: 259-264. (in Russian).
- BECKER V.E., 1983. - Myctophids of the World Ocean. Moskva: Akademiya nauk SSSR (in Russian).
- BECKER V.E. & EVSEENKO S.A., 1987. - Distribution of mesopelagic fishes and biogeographic borders in the southern Pacific Ocean in January-February 1985. *J. Ichthyol. (USSR)*, 27(1): 9-20.
- BOEHLERT G.W. & MUNDY B.C., 1993. - Ichthyoplankton assemblages at seamounts and oceanic islands. *Bull. Mar. Sci.*, 53(2): 336-361.
- BOLIN R.L., 1946. - Lanternfishes from 'Investigator' station 670, Indian Ocean. *Stanford Ichthyol. Bull.*, 3(2): 137-152.
- BOLIN R.L., 1959. - Iniomi: Myctophidae. *Rep. Sci. Results 'Michael Sars' North Atlantic Deep Sea Exped.*, 1910, 4(2, no. 7): 1-45.
- BONECKER A.C.T. & CASTRO M.S., 2006. - Atlas de Larvas de Peixes da Região central da Zona Econômica Exclusiva brasileira. 214 p. Rio de Janeiro: Museu Nacional.
- BRANDT S.B., 1981. - Effects of a warm-core eddy on fish distributions in the Tasman Sea off east Australia. *Mar. Ecol. Progress Series*, 6: 19-23.

- BRANDT S.B., 1983. - Temporal and spatial patterns of lanternfish (family Myctophidae) communities associated with a warm-core eddy. *Mar. Biol.*, 74(3): 231-244.
- BRAUER A., 1904. - Die Gattung *Myctophum*. *Zool. Anzeiger*, 28: 377-404.
- BRAUER A., 1906. - Die Tiefsee-Fische. I. Systematischer Teil. *Wiss. Ergeb. Dtsch. Tiefsee-Exped. Damfer, Valdivia*, 1898-99, 15: 1-420.
- BRIGGS J.C., 1960. - Fishes of worldwide (circumtropical) distribution. *Copeia*, 1960(3): 171-180.
- BRITO A., PASCUAL P.J., FALCÓN J.M., SANCHO A. & GONZÁLEZ G., 2002. - Peces de las Islas Canarias. Catálogo comentado e ilustrado. 419 p. Arafo, Tenerife: Francisco Lemus.
- BROOKS A.L. & SAENGER R.A., 1991. - Vertical size-depth distribution properties of midwater fish off Bermuda, with comparative reviews for other open ocean areas. *Can. J. Fish. Aquat. Sci.*, 48(4): 694-721.
- BULLIS H.R. & THOMPSON J.R., 1965. - Collection by the Exploratory Fishery Vessels Oregon, Silver Bay, Cambat and Pelican made during 1956-60 in the southwestern North Atlantic. *Spec. Sci. Rep., US Fish Wildlife Serv., Fish.*, 510: 1-130.
- BUTLER J.L., MOSER H.G., WATSON W., AMBROSE D.A., CHARTER S.R. & SANDKNOP E.M., 1997. - Fishes collected by midwater trawls during two cruises of the David Starr Jordan in the northeastern Pacific Ocean, April-June and September-October, 1972. *NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC*, 244: 1-83.
- CHILDRESS J.J., PRICE M.H., FAVUZZI J. & COWLES D., 1990. - Chemical composition of midwater fishes as a function of depth of occurrence off the Hawaiian Islands: food availability as a selective factor? *Mar. Biol.*, 105(2): 235-246.
- CLARKE T.A., 1973. - Some aspects of the ecology of lanternfishes (Myctophidae) in the Pacific Ocean near Hawaii. *Fish. Bull. US*, 71(2): 401-433.
- CLARKE T.A., 1980. - Diets of fourteen species of vertically migrating mesopelagic fishes in Hawaiian waters. *Fish. Bull. US*, 78(3): 619-640.
- COHEN D.M., 1973. - Zoogeography of the fishes of the Indian Ocean. In: *The Biology of the Indian Ocean* (Zeitzschel B., ed.), pp. 450-463. Berlin: Springer-Verlag.
- CRADDOCK J.E., BACKUS R.H. & DAHER M.A., 1992. - Vertical distribution and species composition of midwater fishes in warm-core Gulf Stream meander/ring 82-H. *Deep-Sea Res.*, 39: S203-S218.
- CRADDOCK J.E. & HARTEL K.E., 2002. - Myctophidae. In: *The Living Marine Resources of the Western Central Atlantic*. FAO Species Identification Guide for the Eastern Central Atlantic 2. Bony Fishes Part 1 (Acipenseridae to Grammatidae) (Carpenter K.E., ed.), pp. 994-951. Rome: FAO.
- DALPADADO P. & GJØSÆTER J., 1993. - Lanternfishes (Myctophidae) in Sri Lankan waters. *Asian Fish. Sci.*, 6(2): 161-168.
- DONGUY J.-R., ROUGERIE F., COLIN C. & JARRIGE F., 1970. - Résultats des observations physico-chimiques des croisières Caride 4-5 et 6 du N.O. 'Coriolis'. *Rapp. Off. Rech. Sci. Tech. Outre-Mer - Cent. Nouméa, Sect. Océanogr.*, 40: 1-35.
- DOS SANTOS A.P., 2003. - Estudos sobre a taxonomia e a distribuição dos peixes da família Myctophidae (Actinopterygii: Myctophiformes) no sudeste e sul do Brasil. Mestre em Ciências: Instituto Oceanográfico, Universidade de São Paulo.
- DUHAMEL G., 1997. - L'ichtyofaune des îles australes françaises de l'océan Indien. *Cybium*, 21(1): 147-168.
- EMERY W.J., 2001. - Water types and water masses. In: *Encyclopedia of Ocean Sciences* (Steele J., Thorpe S. & Turekian K., eds.), pp. 3179-3187. London: Academic Press.
- ESCHMEYER W.N., 2008. - Catalog of Fishes electronic version (updated 29 August 2008). California Academy of Sciences. Ichthyology. [<http://www.calacademy.org/research/ichthyology/catalog/fishcatsearch.html>].
- FOCK H.O., PUSCH C. & EHRICH S., 2004. - Structure of deep-sea pelagic fish assemblages in relation to the Mid-Atlantic ridge (45°-50°N). *Deep-Sea Res., Part 1, Oceanogr. Res. Pap.*, 51(7): 953-978.
- FOWLER H.W., 1928. - The fishes of Oceania. *Mem. Bernice P. Bishop Mu.*, 10: 1-540.
- FOWLER H.W., 1934. - Descriptions of new fishes obtained 1907 to 1910, chiefly in the Philippine Islands and adjacent seas. *Proc. Acad. Nat. Sci. Philad.*, 85: 233-367.
- FOWLER H.W., 1936. - Marine fishes of West Africa based on the collection of the American Museum Congo Expedition, 1909-15. *Bull. Am. Mus. Nat. Hist.*, 70: 1-605.
- FOWLER H.W., 1938. - The fishes of the George Vanderbilt South Pacific Expedition, 1937. *Monogr. Acad. Nat. Sci. Philad.*, 2: 1-349.
- FRASER-BRUNNER A., 1949. - A classification of the fishes of the family Myctophidae. *Proc. Zool. Soc. Lond.*, 118(4): 1019-1107.
- FROESE R. & PAULY D., 2005. - FishBase. World Wide Web electronic publication. [<http://www.fishbase.org/search.php>].
- FUJII E., 1983. - Myctophidae. In: *Fishes Trawled off Suriname and French Guiana* (Uyeno T., Matsuura K. & Fujii E., eds.), pp. 173-187. Tokyo: Japan Marine Fishery Resource Research Centre.
- FUJII E., 1984. - Myctophidae. In: *The Fishes of the Japanese Archipelago* (Masuda H., Amaoka K., Araga C., Uyeno T. & Yoshino T., eds.), pp. 64-75. Tokyo: Tokai University Press.
- FUJITA K., 1990. - The Caudal Skeleton of Teleostean Fishes. 897 p. Tokyo: Tokai University Press.
- GARMAN S., 1899. - Reports on an expedition off the west coasts of Mexico, Central and South America, and off the Galapagos Islands in charge of Alexander Agassiz, by the U.S. Fish Commission Steamer 'Albatross' during 1891, Lieut. Commander Z.L. Tanner, U.S.N. commanding. XXVI. The fishes. *Mem. Mus. Comp. Zool. Harv. Univ.*, 24: 1-431.
- GARTNER Jr. J.V., HOPKINS T.L., BAIRD R.C. & MILLIKEN D.M., 1987. - The lanternfishes (Pisces, Myctophidae) of the eastern Gulf of Mexico. *Fish. Bull. U.S.*, 85: 81-98.
- GARTNER Jr. J.V., STEELE P. & TORRES J.J., 1989. - Aspects of the distribution of lanternfishes (Pisces, Myctophidae) from the northern Sargasso Sea. *Bull. Mar. Sci.*, 45(3): 555-563.
- GIBBS Jr. R.H., GOODYEAR R.H., KEENE M.J. & BROWN D.W., 1971. - Biological studies of the Bermuda Ocean Acre. II. Vertical distribution and ecology of the lanternfishes (family Myctophidae). *Rep. U.S. Navy Underw. Syst. Cent.*, 1-141.
- GIBBS Jr. R.H. & HURWITZ B.A., 1967. - Systematics and zoogeography of the stomiatoid fishes, *Chauliodus pammelas* and *C. sloani*, of the Indian Ocean. *Copeia*, 1967(4): 798-805.

- GILBERT C.H., 1908. - Reports on the scientific results of the expedition to the tropical Pacific, in charge of Alexander Agassiz, by the U.S. Fish Commission steamer 'Albatross', from August, 1899 to March, 1900, Commander Jefferson F. Moser, U.S.N., commanding. X. The lantern fishes. *Mem. Mus. Comp. Zool. Harv. Univ.*, 26(6): 217-238.
- GJØSÆTER J., 1981. - Abundance and production of lanternfish (Myctophidae) in the western and northern Arabian Sea. *Fisk. dir. Skr. (Havunders.)*, 17: 215-251.
- GJØSÆTER J. & KAWAGUCHI K., 1980. - A review of the world resources of mesopelagic fish. *FAO Fish. Tech. Pap.*, 193: 1-151.
- GOODE G.B. & Bean T.H., 1896. - Oceanic ichthyology, a treatise on the deep-sea and pelagic fishes of the world, based chiefly upon the collections made by the steamers Blake, Albatross and Fish Hawk in the northwestern Atlantic. *Mem. Mus. Comp. Zool. Harv. Univ.*, 1: 1-553.
- GORDON A.L., WEISS R.F., SMETHIE W.M. & WARNER M.J., 1992. - Thermocline and Intermediate Water communication between the South Atlantic and Indian oceans. *J. Geophys. Res.*, 97(C5): 7223-7240.
- GORELOVA T.A., 1978. - The feeding of lanternfishes, *Ceratoscopelus warmingi* and *Bolinichthys longipes*, of the Family Myctophidae in the western equatorial part of the Pacific Ocean. *J. Ichthyol. (USSR)*, 18(4): 588-598.
- GREY M., 1955. - Notes on a collection of Bermuda deep-sea fishes. *Fieldiana: Zool.*, 37: 265-302.
- GRIFFITHS F.B. & WADLEY V.A., 1986. - A synoptic comparison of fishes and crustaceans from a warm-core eddy, the East Australian Current, the Coral Sea and the Tasman Sea. *Deep-Sea Res.*, 33(11-12): 1907-1922.
- GRINDLEY J.R. & PENRITH M.J., 1965. - Notes on the bathypelagic fauna of the seas around South Africa. *Zool. Afr.*, 1(4): 78-240.
- HAFFNER R.E., 1952. - Zoogeography of the bathypelagic fish *Chauliodus*. *System. Zool.*, 1(3): 112-133.
- HARRISON C.M.H., 1967. - On methods for sampling mesopelagic fishes. *Symp. Zool. Soc. Lond.*, 19: 71-126.
- HARTMANN A.R. & CLARKE T.A., 1975. - The distribution of myctophid fishes across the central equatorial Pacific. *Fish. Bull. U.S.*, 73: 633-641.
- HARTMANN J. & WEIKERT H., 1969. - Diurnal vertical migration of a myctophid (Pisces) and its preferred food, two molluscs of the neuston. *Kiel. Meeresforsch.*, 25(2): 328-330.
- HERRING P.J., 2007. - Sex with the lights on? A review of bioluminescent sexual dimorphism in the sea. *J. Mar. Biol. Ass. U.K.*, 87: 829-842.
- HOESE D.F., BRAY D.J., ALLEN G.R. & PAXTON J.R., 2006. - Myctophidae. In: Zoological Catalogue of Australia. 35. Fishes, pp. 508-531. Australia: ARBS & CSIRO Publishing.
- HOPKINS T.L. & GARTNER J.V. Jr., 1992. - Resource-partitioning and predation impact of a low-latitude myctophid community. *Mar. Biol.*, 114(2): 185-197.
- HOPKINS T.L. & LANCRAFT T.M., 1984. - The composition and standing stock of mesopelagic micronekton at 27°N 86°W in the eastern Gulf of Mexico. *Contrib. Mar. Sci.*, 27: 143-158.
- HOPKINS T.L., MILLIKEN D.M., BELL L.M., McMICHAEL E.J., HEFFERNAN J.J. & CANO R.V., 1981. - The landward distribution of oceanic plankton and micronekton over the west Florida continental shelf as related to their vertical distribution. *J. Plankt. Res.*, 3(4): 645-658.
- HOPKINS T.L., SUTTON T.T. & LANCRAFT T.M., 1997. - The trophic structure and predation impact of a low latitude midwater fish assemblage. *Progr. Oceanogr.*, 38(3): 205-239.
- HUBBS C.L. & LAGLER K.M., 1947. - Fishes of the Great Lakes region (1958 edition). *Cranbrook Inst. Sci. Bull.*, 26: 1-135.
- HULLEY P.A., 1972a. - A report on the mesopelagic fishes collected during the deep-sea cruises of R.S. 'Africana II', 1961-1966. *Ann. S. Afr. Mus.*, 60(6): 197-236.
- HULLEY P.A., 1972b. - Mesopelagic fishes from Vema Seamount (IK Station 52). *Ann. S. Afr. Mus.*, 60(7): 237-244.
- HULLEY P.A., 1981. - Results of the research cruises of FRV 'Walther Herwig' to South America. LVIII. Family Myctophidae (Osteichthyes, Myctophiformes). *Archiv. Fisch. Wiss.*, 31(1): 1-300.
- HULLEY P.A., 1984a. - Myctophidae. In: Fishes of the North-eastern Atlantic and the Mediterranean. Vol. 1 (Whitehead P.J.P., Bauchot M.-L., Hureau J.-C., Nielsen J.N. & Tortonese E., eds.), pp. 429-483. Paris: Unesco.
- HULLEY P.A., 1984b. - The South African Museum's Meiring Naude cruises. 14. Family Myctophidae (Osteichthyes, Myctophiformes). *Ann. S. Afr. Mus.*, 93(2): 53-96.
- HULLEY P.A., 1986a. - Family 86: Myctophidae. In: Smiths' Sea Fishes (Smith M.M. & Heemstra P.C., eds.), pp. 282-321. Johannesburg: Macmillan.
- HULLEY P.A., 1986b. - Lanternfishes of the southern Benguela region. Part 1. Faunal complexity and distribution. *Ann. S. Afr. Mus.*, 97(7): 227-249.
- HULLEY P.A., 1989. - Lanternfishes (Osteichthyes, Myctophidae) from the region of Saint-Paul and Amsterdam islands. *Mésogée*, 49: 40-58.
- HULLEY P.A., 1990. - Myctophidae. In: Check-list of Fishes of the Eastern Tropical Atlantic. Vol. 1 (Quéro J.-C., Hureau J.-C., Karrer C., Post A. & Saldanha L., eds.), pp. 398-467. Paris: Unesco.
- HULLEY P.A., 1992. - Upper-slope distributions of oceanic lanternfishes (family: Myctophidae). *Mar. Biol.*, 114(3): 365-383.
- HULLEY P.A. & DUHAMEL, G. 1990. - Report on prélèvements RMT - fishes. In Les rapports des campagnes à la mer aux îles Saint-Paul et Amsterdam (Arnaud P., ed). *Publ. Mission Rech. Terres Australes Antarct. Fr.*, 86-04: 80-89.
- HULLEY P.A. & DUHAMEL G., 1997. - Lanternfishes (Myctophidae) collected during the 1971-Pelagia cruise of R.V. 'Coriolis' in the south-west Pacific Ocean. *Cybium*, 21(3): 299-317.
- HULLEY P.A. & KREFFT G., 1985. - A zoogeographic analysis of the fishes of the family Myctophidae (Osteichthyes, Myctophiformes) from the 1979-Sargasso Sea Expedition of R.V. 'Anton Dohrn'. *Ann. S. Afr. Mus.*, 96(2): 19-53.
- HULLEY P.A. & LUTJEHARMS J.R.E., 1995. - The south-western limit for the warm-water, mesopelagic ichthyofauna of the Indo-West Pacific: lanternfish (Myctophidae) as a case study. *S. Afr. J. Mar. Sci.*, 15: 185-205.
- HULLEY P.A. & PAXTON J.R., in press. - Family Myctophidae. In The Living Marine Resources of the Eastern Central Atlantic. FAO Species Identification Guide for the Eastern Central Atlantic (Carpenter K.E., ed.). Rome: FAO.
- IWAMI T. & KUBODERA T., 1990. - Mesopelagic fishes collected with 10-foot IKPT in the Indian sector of the Antarctic Ocean and its neighboring waters during the Jare-28 cruise, 1987. *Proc. NIPR Symp. Polar Biol.*, 3: 64-70.

- JAHN A.E. & BACKUS R.H., 1976. - On the mesopelagic fish faunas of Slope Water, Gulf Stream, and northern Sargasso Sea. *Deep-Sea Res.*, 23: 223-234.
- JOHNSON R.K., 1975. - A new myctophid fish, *Bolinichthys distofax*, from the western and central North Pacific Ocean, with notes on other species of *Bolinichthys*. *Copeia*, 1975(1): 53-60.
- JOHNSON R.K., 1982. - Fishes of the families Evermannellidae and Scopelarchidae: systematics, morphology, interrelationships, and zoogeography. *Fieldiana: Zool.*, 12(NS): 1-252.
- KAILOLA P.J., 1987. - The fishes of Papua New Guinea. A revised and annotated checklist. Vol. 1. Myxinidae to Synbranchidae. *Res. Bull. Dep. Fish. Mar. Resour., Port Moresby, Papua New Guinea*, 41: 1-194.
- KARNELLA C., 1987. - Family Myctophidae, lanternfishes. In: Biology of Midwater Fishes of the Bermuda Ocean Acre (Gibbs Jr. R.H. & Krueger W.H., eds.). *Smith. Contrib. Zool.*, 452: 51-168.
- KINZER J., BÖTTGER-SCHNACK R. & SCHULTZ K., 1994. - Aspects of horizontal distribution and diet of myctophid fish in the Arabian Sea with reference to the deep water oxygen deficiency. *Deep-Sea Res.*, 40(3): 783-800.
- KOTTHAUS A., 1972a. - Die meso- und bathypelagischen Fische der 'Meteor'-Rossbreiten-Expedition 1970 (2. und 3. Fahrtabschnitt). *Meteor Forsch.-Ergeb.*, 11: 1-28.
- KOTTHAUS A., 1972b. - Fische des Indischen Ozeans. Ergebnisse der ichthyologischen Untersuchungen während der Expedition des Forschungsschiffes "Meteor" in den Indischen Ozean, Oktober 1964 bis Mai 1965. A. Systematischer Teil, IX. Iniomi (Nachtrag: Fam. Myctophidae). *Meteor Forsch.-Ergeb.*, 12: 12-35.
- KREFFT G., 1973. - Additional notes: Myctophidae. In: Checklist of the Fishes of the North-eastern Atlantic and of the Mediterranean. II (Hureau J.-C. & Monod T., eds.), pp. 318-319. Paris: Unesco.
- KREFFT G., 1978. - Distribution patterns of oceanic fishes in the Atlantic Ocean. *Rev. Trav. Inst. Pêches Mar.*, 40(3/4): 439-460.
- KREFFT G. & BECKER V.E., 1973. - Myctophidae. In: Checklist of Fishes of the North-eastern Atlantic and Mediterranean. I (Hureau J.-C. & Monod T., eds.), pp. 171-198. Paris: Unesco.
- KRUEGER W.H., GIBBS Jr. R.H., KLECHNER R.C., KELLER A.A. & KEENE M.J., 1977. - Distribution and abundance of mesopelagic fishes on cruises 2 and 3 at Deepwater Dumpsite 106. *NOAA Dumpsite Eval. Rep.*, 77-1(2): 377-422.
- KUBOTA T., SAIKI E. & KOBAYAKAWA M., 1989. - Note on the seasonal occurrence and vertical distribution of myctophid fishes in Suruga Bay, Central Japan. *Bull. Inst. Ocean. Res. Dev., Tokai Univ.*, 10: 21-30.
- LEGAND M., BOURRET P., FOURMANOIR P., GRANDPERLIN R., GUEREDRAT J.A., MICHEL A., RANCUREL P., REPELIN R. & ROGER C., 1972. - Relations trophiques et distributions verticales en milieu pélagique dans l'océan Pacifique intertropical. *Cah. Orstom (Sér. Océanogr.)*, 10(4): 303-393.
- LEMASSON L., MAGNIER Y. & PITON B., 1967a. - Résultats des observations physico-chimiques de la croisière "Bora 1" du N.O. 'Coriolis'. *Rapp. Sci. Off. Rech. Sci. Tech. Outre Mer*, 9: 1-32.
- LEMASSON L., PITON B. & JARRIGE F., 1967b. - Résultats des observations physico-chimiques de la croisière "Bora 3" du N.O. 'Coriolis'. *Rapp. Sci. Off. Rech. Sci. Tech. Outre Mer*, 11: 1-32.
- LINKOWSKI T.B., 1991. - Otolith microstructure and growth patterns during the early life history of lanternfishes (family Myctophidae). *Can. J. Zool.*, 69: 1777-1792.
- LOEB V.J., 1979a. - Larval fishes in the zooplankton community of the North Pacific Central Gyre. *Mar. Biol.*, 53(2): 173-191.
- LOEB V.J., 1979b. - Vertical distribution and development of larval fishes in the North Pacific Central Gyre during summer. *Fish. Bull. U.S.*, 77(4): 777-793.
- LOEB V.J., 1980. - Patterns of spatial and species abundance within the larval fish assemblage of the North Pacific Central Gyre during late summer. *Mar. Biol.*, 60(2-3): 189-200.
- LOEB V.J., 1986. - Importance of vertical distribution studies in biogeographic understanding: eastern tropical Pacific vs North Pacific central gyre ichthyoplankton assemblages. *Unesco Tech. Pap. Mar. Sci.*, 49: 177-181.
- LONGHURST A., 1998. - Ecological Zoogeography of the Sea. 398 p. San Diego: Academic Press.
- LONGHURST A., SATHYENDRANATH S., PLATT T. & CAVERHILL C., 1995. - An estimate of global primary production in the ocean from satellite radiometer data. *J. Plankt. Res.*, 17(6): 1245-1271.
- LOUW E., 1977. - The South African Museum's 'Meiring Naude' Cruises. Part 1. Station data 1975, 1976. *Ann. S. Afr. Mus.*, 72(8): 147-159.
- LOUW E., 1980. - The South African Museum's 'Meiring Naude' Cruises. Part 10. Station data 1977, 1978, 1979. *Ann. S. Afr. Mus.*, 81 (5): 187-205.
- MAGNIER Y., HISARD P., JARRIGE F., RUAL P. & VOITURIEZ B., 1967. - Résultats des observations physico-chimiques de la croisière "Bora 4" du N.O. 'Coriolis'. *Rapp. Sci. Off. Rech. Sci. Tech. Outre Mer*, 12: 1-28.
- MAUL G.E., 1948. - Lista sistemática dos peixes assinalados nos mares de Madeira e índice alfabético. In: Vertebrados da Madeira. 2. Peixes (2ª edit.) (de Noronha A.C. & Sarmiento A.A., eds.), pp. 135-181. Madeira, Portugal: Junta Geral do Distrito Autónomo do Funchal.
- MCGINNIS R.F., 1974. - Biogeography of lanternfishes (Family Myctophidae) south of 30°S. Unpubl. Ph.D. diss., Univ. of Southern California, Los Angeles.
- MCGINNIS R.F., 1982. - Biogeography of lanternfishes (Myctophidae) south of 30°S. *Antarct. Res. Ser., Washington*, 35: 1-110.
- McKELVIE D.S., 1985a. - Discreteness of pelagic faunal regions. *Mar. Biol.*, 88(2): 125-133.
- McKELVIE D.S., 1985b. - The mesopelagic fish fauna of the Newfoundland Basin. *Can. J. Zool.*, 63(9): 2176-2182.
- MENON A.G.K. & RAO K.V.R., 1971. - Further notes on the fish types in the R.I.M.S. Investigator collections. *Copeia*, 1971(2): 343-344.
- MENON A.G.K. & YAZDANI G.M., 1968. - Catalogue of type specimens in the Zoological Survey of India, Part 2, Fishes. *Rec. Zool. Survey India*, 61(1/2): 91-190.
- MERRETT N.R., BADCOCK J., EHRICH S. & HULLEY P.A., 1986. - Preliminary observations on the near-bottom ichthyofauna of the Rockall Trough: a contemporaneous investigation using commercial-sized midwater and demersal trawls. In: The Oceanography of the Rockall Channel: a Symposium Organized jointly by the Royal Society of Edinburgh and the SMBA and held in the Wolfson Theatre, Royal Society of Edinburgh on 22-29 March 1985 (Mauchline J., ed). *Proc. R. Soc. Edinburgh*, 88(B): 312-314.

- MISRA K.S., 1949. - Notes on Alcock's type-specimen of the deep sea fish, *Scopelus pyrsobolus*, from the Bay of Bengal (Pisces). *J. Zool. Soc. India*, 1(1): 37-38.
- MISRA K.S., 1952. - An aid to the identification of the fishes of India, Burma and Ceylon. II. Clupeiformes, Bathyclupeiformes, Galaxiiformes, Scopeliformes and Ateleopiformes. *Rec. Indian Mus.*, 50: 367-422.
- MOORE J.A., HARTEL K.E., CRADDOCK J.E. & GALBRAITH J.K., 2003. - An annotated list of deepwater fishes from off the New England region, with new area records. *Northeast. Nat.*, 10(2): 159-248.
- MOORE J.A., VECCHIONE M., COLLETTE B.B., GIBBONS R. & HARTEL K.E., 2004. - Selected fauna of Bear Seamount (New England Seamount chain), and the presence of "natural invader" species. *Arch. Fish. Mar. Res.*, 51(1-3): 241-250.
- MOSER H.G. & AHLSTROM E.H., 1972. - Development of the lanternfish, *Scopelopsis multipunctatus* Brauer 1906, with a discussion of its phylogenetic position in the family Myctophidae and its role in a proposed mechanism for the evolution of photophore patterns in lanternfishes. *Fish. Bull. U.S.*, 70(3): 541-564.
- MOSER H.G. & AHLSTROM E.H., 1974. - Role of larval stages in systematic investigations of marine teleosts: the Myctophidae, a case study. *Fish. Bull. U.S.*, 72(2): 391-413.
- MOSER H.G., AHLSTROM E.H. & PAXTON J.R., 1984. - Myctophidae: development. In: Ontogeny and Systematics of Fishes, based on an International Symposium dedicated to the memory of Elbert Halvor Ahlstrom (Moser H.G., Richards W.J., Cohen D.M., Fahay M.P., Kendall Jr. A.W. & Richardson S.L., eds.). *Spec. Publ. Am. Soc. Ichthyol. Herpetol.*, 1(1): 218-239.
- MOSER H.G. & WATSON W., 2001. - Preliminary guide to the identification of the early life history stages of Myctophiform fishes of the Western Central Atlantic. *NOAA Tech. Rep. Natl. Mar. Fish. Serv.*, 453: 1-118.
- MOSER H.G. & WATSON W., 2006. - Myctophidae: Lanternfishes. In: Early Stages of Atlantic Fishes (Richards W.L., ed.), pp. 473-579. Boca Raton: Taylor & Francis.
- MUNDY B.C., 2005. - Checklist of the fishes of the Hawaiian Archipelago. *Bishop Mus. Bull. Zool.*, 6: 1-703.
- NAFPAKTITIS B.G., 1978a. - Myctophidae. In: FAO Species Identification Sheets for Fishery Purposes. Western Central Atlantic (fishg area 31). 1 (Fischer W., ed.), pp. 1-6. Rome: FAO.
- NAFPAKTITIS B.G., 1978b. - Systematics and distribution of lanternfishes of the genera *Lobianchia* and *Diaphus* (Myctophidae) in the Indian Ocean. *Sci. Bull. Natl. Hist. Mus. Los Angeles Cty.*, 30: 1-92.
- NAFPAKTITIS B.G., BACKUS R.H., CRADDOCK J.E., HAEDRICH R.L., ROBISON B.H. & KARNELLA C., 1977. - Family Myctophidae. In: Fishes of the Western North Atlantic. 7 (Gibbs Jr. R.H., Berry F.H., Bölske J.E., Cohen D.M., Collette B.B., Eschmeyer W.N., Mead G.W., Merriman D. & Pietsch T.W., eds.). *Mem. Sears Found. Mar. Res.*, 1(7): 13-265.
- NAFPAKTITIS B.G. & NAFPAKTITIS M., 1969. - Lanternfishes (family Myctophidae) collected during Cruises 3 and 6 of R/V 'Anton Bruun' in the Indian Ocean. *Bull. Los Angeles Cty. Mus. Nat. Hist.*, 5: 1-79.
- NAIR V.R., 1977. - The chaetognaths of the Indian Ocean. *Proc. Symp. Warm Water Zooplankton, Natl. Inst. Oceanogr. Goa*, 168-196.
- NAIR V.R. & MADHUPRATAP M., 1984. - Latitudinal range of epipelagic Chaetognatha and Ostracoda in the western tropical Indian Ocean. *Hydrobiologia*, 112: 209-216.
- NAKABO T., 2000. - Myctophidae lanternfishes. In: Fishes of Japan with Pictorial Keys to the Species. 2nd edit. (Nakabo T., ed.), pp. 378-399. Tokyo: Tokai University Press. (in Japanese)
- NAKABO T., 2002. - Myctophidae lanternfishes. In: Fishes of Japan with Pictorial Keys to the Species, English edit. (Nakabo T., ed.), pp. 378-399. Tokyo: Tokai University Press.
- NEIGHBORS M.A. & NAFPAKTITIS B.G., 1982. - Lipid compositions, water contents, swimbladder morphologies and buoyancies of nineteen species of midwater fishes (18 myctophids and 1 neoscopelid). *Mar. Biol.*, 66(3): 207-215.
- NELLEN W. & RUSELER S., 2004. - Composition, horizontal and vertical distribution of ichthyoplankton in the Great Meteor Seamount area in September 1988. *Arch. Fisch. Wiss.*, 51(1-3): 132-164.
- NEW A.L., STANSFIELD K., SMYTHE-WRIGHT D. & SMEED D.A., 2005. - Physical and biochemical aspects of the flow across the Mascarene Plateau in the Indian Ocean. *Philos. Trans. R. Soc. (A)*, 363(A): 151-168.
- NORMAN J.R., 1930. - Oceanic fishes and flatfishes collected in 1925-27. *'Discovery' Rep.*, 2: 261-370.
- OLIVAR M.P., BECKLEY L.E. & MOSER H.G., 1999. - Lanternfish larvae from the Agulhas Current (SW Indian Ocean). *Sci. Mar.*, 63(2): 101-120.
- OZAWA T., 1986. - Early life history of the family Myctophidae in the ocean off southern Japan. In: Studies on the Oceanic Ichthyoplankton in the Western North Pacific (Ozawa T., ed.), pp. 114-188. Fukuoka-shi: Kyushu University Press.
- PARIN N.V., ANDRIASHEV A.P., BORODULINA O.D. & TCHUVASOV V.M., 1974. - Midwater fishes of the south-western Atlantic Ocean. *Tr. Inst. Okeanol.*, 98: 76-140. (in Russian)
- PARIN N.V., BECKER V.E., BORODULINA O.D., KARMOVSKAYA E.S., FEDORYAKO B.I., SHCHERBACHEV J.N., POKHILSKAYA G.N. & TCHUVASOV V.M., 1977. - Midwater fishes in the western tropical Pacific Ocean and the seas of the Indo-Australian archipelago. *Tr. Inst. Okeanol.*, 107: 68-188. (in Russian)
- PARIN N.V., BECKER V.E., BORODULINA O.D. & TCHUVASOV V.M., 1973. - Deep-sea pelagic fishes of the south-eastern Pacific Ocean. *Tr. Inst. Okeanol.*, 94: 71-172. (in Russian)
- PARIN N.V., BORODULINA O.D., KONOVALENKO I.I. & KOTLYAR A.N., 1990a. - Oceanic pelagic fishes of the southern east Pacific (composition of fauna and geographic distribution). *Proc. P.P. Shirshov Inst. Oceanol., Russ. Acad. Sci.*, 25: 192-222. (in Russian)
- PARIN N.V., GORELOVA T.A. & BORODULINA O.D., 1990b. - Feeding and trophic relationships of fishes inhabiting the Nazca and Sala y Gomez submarine ridges. *Tr. Inst. Okeanol.*, 125: 37-57. (in Russian)
- PARIN N.V., NESIS K.N., SAGAI DACHNY A.Y. & SCHERBACHEV Y., 1993. - Fauna of Walters Shoal, a seamount in the southwestern Indian Ocean. *Tr. Inst. Okeanol.*, 128: 199-216. (in Russian)
- PARR A.E., 1928. - Deep-sea fishes of the order Iniomi from the waters around the Bahamas and Bermuda Islands with annotated keys to the Suidae, Myctophidae, Scopelarchidae, Evermannellidae, Omosudidae, Cetomimidae and Rondelettiidae of the world. *Bull. Bingham Oceanogr. Collect., Yale Univ.*, 3(3): 1-193.

- PARR A.E., 1929. - Notes on the species of myctophine fishes represented by type specimens in the United States National Museum. *Proc. U.S. Natl. Mus.*, 76(10): 1-47.
- PARR A.E., 1934. - Studies of the Myctophinae in the Museum of Comparative Zoology. I. Revision of type specimens. II. Myctophinae collected by C. O'D. Iselin in the northern Atlantic in 1928. *Bull. Mus. Comp. Zool. Harv. Univ.*, 77(2): 41-65.
- PAXTON J.R., 1972. - Osteology and relationships of the lanternfishes (Family Myctophidae). *Sci. Bull. Nat. Hist. Mus. Los Angeles Cty.*, 13: 1-81.
- PAXTON J.R., 1979. - Nominal genera and species of lanternfishes (family Myctophidae). *Contrib. Sci., Los Angeles Cty. Mus. Nat. Hist.*, 322: 1-28.
- PAXTON J.R., HOESE D.F., ALLEN G.R. & HANLEY J.E., 1989. - Myctophidae (122). In: Zoological Catalogue of Australia. 7. Pisces: Petromyzontidae to Carangidae, pp. 253-270. Canberra: Australian Government Publishing Service.
- PAXTON J.R., AHLSTROM E.H. & MOSER H.G., 1984. - Myctophidae: relationships. In: Ontogeny and systematics of fishes (Moser H.G., Richards W.J., Cohen D.M., Fahay M.P., Kendall Jr. A.W. & Richardson S.L., eds.) *Am. Soc. Ichthyol. Herpetol. Spec. Publ.*, 1: 239-244.
- PAXTON J.R. & HULLEY P.A., 1999. - Family Myctophidae. In: The Living Marine Resources of the Western Central Pacific. 3. Batoid fishes, chimaeras and bony fishes part 1 (Elopidae to Linophrynidae) (Carpenter K.E. & Niem V.H., eds.), pp. 1957-1963. Rome: FAO.
- PAXTON J.R. & HULLEY P.A. 2000. - Family Myctophidae (lanternfishes). In: A Checklist of the Fishes of the South China Sea. (Randall J.R. & Lim K.K.P., eds.). *Raffles Bull. Zool.*, 2000(Suppl. 8): 593-594.
- PAXTON J.R., LAVENBERG R.J. & SOMMER C., 1995. - Myctophidae. In: Guía FAO para la identificación de especies para los Fines de la Pesca. Pacífico centro-oriental. Vol. III. Vertebrados - Parte 2 (Fischer W., Krupp F., Sommer C., Carpenter K.E. & Niem V.H., eds.), pp. 1315-1321. Rome: FAO.
- PICKARD G.L. & EMERY W.J., 1992. - Descriptive Physical Oceanography. 6th edit. 241 p. Oxford: Pergamon.
- POST A., 1987. - Station lists and technical data of the pelagic transects of FRVs 'Walther Herwig' and 'Anton Dohrn' in the Atlantic Ocean 1966 to 1986. *Mitt. Inst. Seefisch.*, 42: 1-67.
- POSTEL E., 1959. - Liste commentée des poissons signalés dans l'Atlantique tropico-oriental nord, du Cap Spartel au Cap Roxo, suivie d'un bref aperçu sur leur répartition bathymétrique et géographique. *Bull. Soc. Sci. Bretagne*, 34: 129-169.
- PUSCH C., BECKMANN A., PORTEIRO F.M. & WESTERNHAGEN H.v., 2004. - The influence of seamounts on mesopelagic fish communities. *Arch. Fisch. Wiss.*, 51(1-3): 165-186.
- QUÉRO J.-C., 1977. - Famille des Myctophides. In: Poissons des Côtes nord-ouest africaines (Campagnes de la 'Thalassa' 1962, 1968, 1971 et 1973) (Maurin C., Bonnet M. & Quéro J.-C., eds.). *Rev. Trav. Off. Sci. Tech. Pêches Mar.*, 41(1): 62-76.
- RAO T.S.S., 1979. - Zoogeography of the Indian Ocean. In: Zoogeography and Diversity of Plankton (van der Spoel S. & Pierrot-Bults A.C., eds.), pp. 254-292. London: Edward Arnold.
- REPELIN R., GUEREDRAT J.A., MARTEAU J., RIVATON J. & VELAYOUDON H., 1969. - Croisières Caride I. Zooplankton-micronecton. *Rapp. Off. Rech. Sci. Tech. Outre-Mer - Cent. Nouméa. Sect. Océanogr.*, 35: 1-64.
- RICHARDS W.J., 1984. - Kinds and abundance of fish larvae in the Caribbean Sea and adjacent areas. *NOAA Tech. Rep. Natl. Mar. Fish. Serv.*, SSRF-776: 1-54.
- RIVATON J. & BOURRET P., 1999. - Les otolithes des poissons de l'Indo-Pacifique. *Doc. Sci. Tech.*, 2(2): 1-378.
- ROTSCHI H., HISARD P., MAGNIER Y. & NOEL J., 1967. - Résultats des observations physico-chimiques de la croisière Bora II du N.O. 'Coriolis'. *Rapp. Sci. Off. Rech. Sci. Tech. Outre Mer*, 10: 1-35.
- SASSA C., KAWAGUCHI K., HIROTA Y. & ISHIDA M., 2007. - Distribution depth of the transforming stage larvae of myctophid fishes in the subtropical-tropical waters of the western North Pacific. *Deep-Sea Res.* 1, 54(12): 2181-2193.
- SCHLITZER R., 2005. - Ocean Data-View. <http://www.awi-bremerhaven.de/GEO/ODV>.
- SHINOHARA G., ENDO H. & MATSUURA K., 1996. - Deep-water fishes collected from the Pacific coast of northern Honshu, Japan. *Mem. Natl. Sci. Mus., Tokyo*, 29: 153-185.
- SHINOHARA G., ENDO H., MATSUURA K., MACHIDA Y. & HONDA S., 2001. - Annotated checklist of the deepwater fishes from Tosa Bay, Japan. *Natl. Sci. Mus. Monogr.*, 20: 283-343.
- SHINOHARA G. & MATSUURA K., 1997. - Annotated checklist of deep-water fishes from Suruga Bay, Japan. *Natl. Sci. Mus. Monogr.*, 12: 269-318.
- SHINOHARA G., SATO T., AONUMA Y., HORIKAWA H., MATSUURA K., NAKABO T. & SATO K., 2005. - Annotated checklist of the deep-sea fishes from the waters around the Ryukyu Islands, Japan. *Natl. Sci. Mus. Monogr.*, 29: 385-452.
- SMALE M.J., WATSON G. & HECHT T., 1995. - Otolith atlas of southern African marine fishes. *Ichthyol. Monogr. JLB Smith Inst. Ichthyol.*, 1: 1-253.
- STIASSNY M.L.J., 1996. - Basal ctenosquamate relationships and the interrelationships of the myctophiform (scopelomorph) fishes. In: Interrelationships of Fishes (Stiassny M.L.J., Parenti L.R. & Johnson G.D., eds.), pp. 405-426. San Diego: Academic Press.
- STICKNEY D.G. & TORRES J.J., 1989. - Proximate composition and energy content of mesopelagic fishes from the eastern Gulf of Mexico. *Mar. Biol.*, 103: 13-24.
- SUDA A., 1973. - Tuna fisheries and their resources in the Indian Ocean. In: The Biology of the Indian Ocean (Zeitzschel B., ed.), pp. 431-449. Berlin: Springer-Verlag.
- TÅNING Å.V., 1928. - Synopsis of the scopelids in the North Atlantic. *Vidensk. Medd. Dan. Naturhist. Foren. København*, 86: 49-69.
- TINKER S.W., 1978. - Fishes of Hawaii, a Handbook of the Marine Fishes of Hawaii and the Central Pacific Ocean. 568 p. Honolulu: Hawaiian Service Inc.
- TOLMAZIN D., 1985. - Elements of Dynamic Oceanography. 191 p. London: Allen and Unwin.
- TOMCZAK M. & GODFREY J.S., 2002. - Regional Oceanography - an introduction. 391 p. <http://www.es.flinders.edu.au/~mattom/regoc/pdf version.html>.
- TORTONESE E., 1972. - Risultati ittologici di alcune crociere nel Mediterraneo e nel vicino Atlantico (1970-71). *Ann. Mus. Civ. Stor. Nat. Giacomo Doria*, 79: 18-26.
- TSARIN S.A., 1996. - Ecological complexes of Myctophidae in the sound scattering layers in the Equatorial Province of the Indian Ocean. *J. Ichthyol. (USSR)*, 36(9): 747-752.
- VAN DER SPOEL S. & BLEEKER J., 1991. - Distribution of Myctophidae (Pisces, Myctophiformes) during four seasons in the mid North Atlantic. *Bijdr. Dierkunde*, 61(2): 89-106.

- VINICHENKO V.I., 1997. - Russian investigations and deep water fishery on the Corner Rising Seamount in Subarea 6. *NAFO Sci. Counc. Stud.*, 30: 41-49.
- VOITURIEZ B., RUAL P., HISARD P. & LE CORVAISIER A., 1969. - Résultats des Observations physico-chimiques des croisières Caride 1-2 et 3. *Rapp. Off. Rech. Sci. Tech. Outre-Mer - Cent. Nouméa. Sect. Océanogr.*, 36: 1-24.
- WANG J.T.-A. & CHEN C.-T., 2001. - A review of lanternfishes (families Myctophidae and Neoscopelidae) and their distribution around Taiwan and the Tungsha Islands with notes on seventeen new records. *Zool. Stud.*, 40(2): 103-126.
- WILLIS J.M., 1984. - Mesopelagic fish faunal regions of the north-east Pacific. *Biol. Oceanogr. (N.Y.)*, 3: 167-185.
- WISNER R.L., 1976. - The taxonomy and distribution of lanternfishes (family Myctophidae) of the eastern Pacific Ocean. *Navy Ocean Res. Dev. Act. Rep.*, 3: 1-229.
- WORTHINGTON L.V., 1981. - The water masses of the world ocean: some results of a fine-scale census. In: *Evolution of Physical Oceanography* (Warren B.A. & Wunsch C., eds.), pp. 42-69. Cambridge, MA: MIT Press.
- WYRTKI K., 1971. - *Oceanographic Atlas of the Indian Ocean*. 531 p. Washington, DC: National Science Foundation.
- WYRTKI K., 1973a. - An equatorial jet in the Indian Ocean. *Science*, 181: 263-264.
- WYRTKI K., 1973b. - Physical oceanography of the Indian Ocean. In: *The Biology of the Indian Ocean* (Zeitzschel B., ed.), pp. 18-36. Berlin: Springer-Verlag.
- YAMAGUCHI M., MIYA M., OKIYAMA M. & NISHIDA M., 2000. - Molecular phylogeny and larval morphological diversity of the lanternfish genus *Hygophum* (Teleostei: Myctophidae). *Mol. Phylogenet. Evol.*, 15(1): 103-114.
- YANG J. & HUANG Z., 1992. - Description of a new species of lanternfish *Bolinichthys* (family Myctophidae) from the South China Sea. *Trop. Oceanol.*, 11(2): 77-82.
- YOU Y. & TOMCZAK M., 1993. - Thermocline circulation and ventilation in the Indian Ocean derived from water mass analysis. *Deep-Sea Res. I*, 40: 13-56.
- Reçu le 7 septembre 2009.
Accepté pour publication le 2 février 2010.